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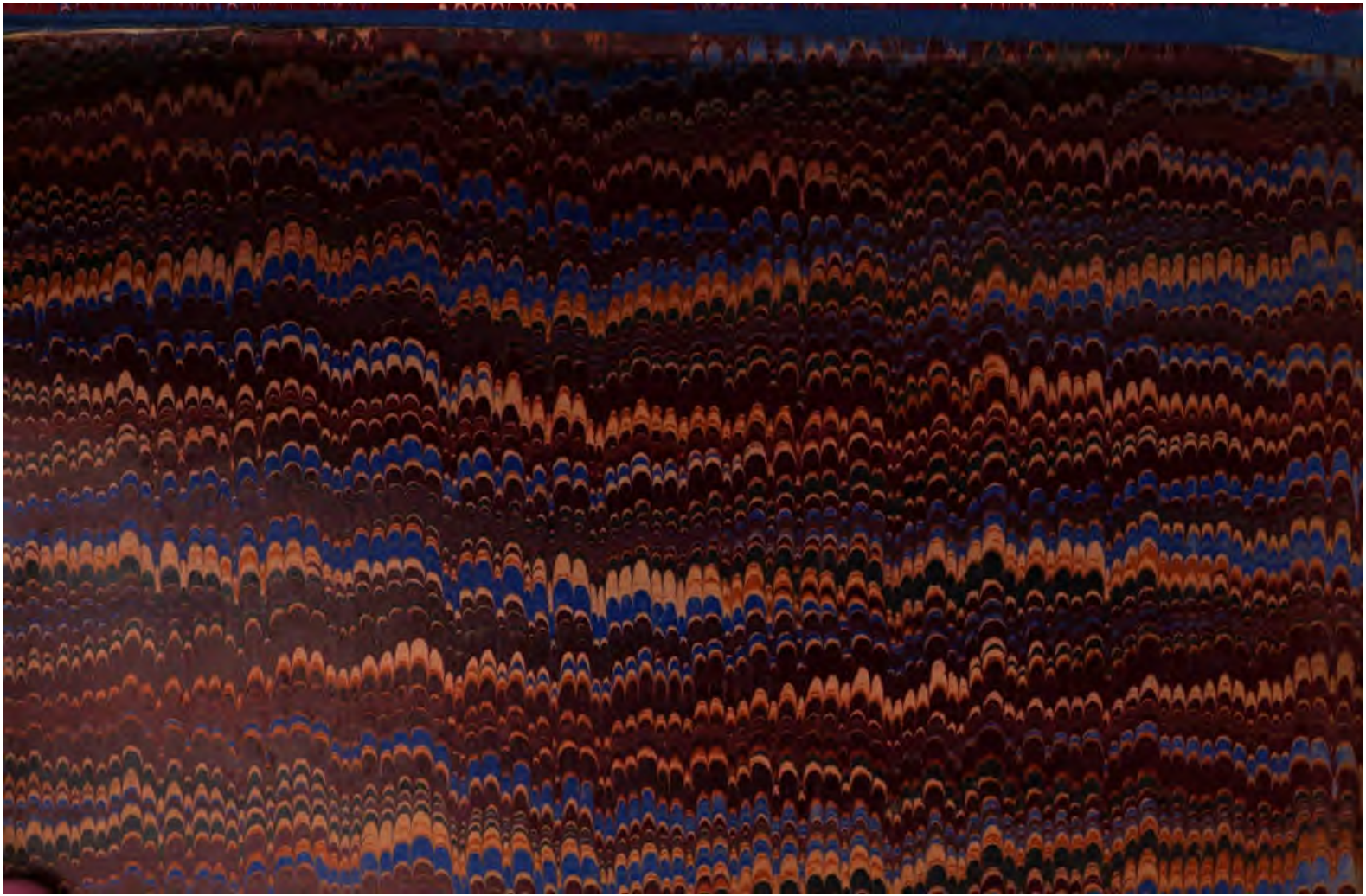
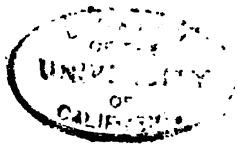


MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. NO. 1. NOVEMBER 1896.



INVITATION OF LADIES TO THE ORDINARY MEETINGS OF THE SOCIETY.

The attention of Fellows is called to the fact that Ladies are only admitted to the Ordinary Evening Meetings of the Society by special invitation of the President, sanctioned by the Council. The invitations are issued at the commencement of each Session.

THE LIBRARY.

The attention of Fellows is requested to the following resolution of Council at their meeting of 1896, November 13 :—

"All books must be actually returned to the Library on or before the second Friday in November in each year, and not taken out again till the following Friday without special permission."

This resolution will take effect for the first time in 1897.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS, ABSTRACTS OF PAPERS, AND

REPORTS OF THE PROCEEDINGS

OF THE SOCIETY

FROM NOVEMBER 1896 *TO NOVEMBER* 1897.

VOL. LVII.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. NOVEMBER 13, 1896. No. 1

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

Lewis Evans, J.P., F.S.A., Barnes Lodge, King's Langley, Herts; and

John Anderton Greenwood, B.A., LL.M., Brooklyn, Earl's Court Square, S.W.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

William Johnston, Saint Nicholas House, Westgate Street, Gloucester (proposed by J. McCarthy);

George Edward Lumsden, Assistant Secretary of the Province of Ontario, 57 Elm Avenue, Toronto, Canada (proposed by S. W. Burnham);

Major Percy Alexander MacMahon, R.E., F.R.S., Artillery College, Woolwich, and 52 Shaftesbury Avenue, W. (proposed by A. A. Common);

Louis C. H. Maston, Banker, San Francisco, California, U.S.A (proposed by H. H. Turner);

Beauchamp Prideaux Selby, J.P., Pawston, Cornhill-on-Tweed, R.S.O., Northumberland (proposed by John Browning);

J. E. de Villiers, Government Surveyor, Cape Town (proposed by David Gill); and
John Watson, Norman Villa, Glossop Road, Sheffield (proposed by W. J. B. Roome).

Two hundred and twenty presents were announced as having been received since the last meeting, including, amongst others:—

Cayley's Collected Mathematical Papers, vol. x., presented by the Cambridge University Press; Catalog der Astronomischen Gesellschaft, Zone +15° bis +20°, presented by the Society; the Indian Calendar, with tables of eclipses, &c., presented by Robert Sewell; Laplace, Œuvres Complètes, tome xi., presented by the Paris Academy; Lœwy and Puiseux, Atlas Photographique de la Lune, fasc. I., presented by the authors; W. T. Lynn, Remarkable Eclipses, presented by the author; Map of India, showing path of eclipse of January 1898, presented by the Surveyor-General; *Venus*-Durchgänge, 1874 und 1882, Bericht über die deutschen Beobachtungen, Band vi., presented by the German Transit of *Venus* Commission; Original negatives of *Jupiter* and the Moon, photographs of *Mars*, and Sun-spot, and portrait of W. Chauvenet, presented by the Lick Observatory; Series of thirteen transparencies of the Milky Way, &c., presented by E. E. Barnard; series of fifteen photographs of the Milky Way, &c., presented by Max Wolf; Photographs of the spectrum of the zinc arc, presented by Henry Crew.

Mean Areas and Heliographic Latitudes of Sun-spots in the Year 1894, deduced from Photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius.

(*Communicated by the Astronomer Royal.*)

The results here given are in continuation of those printed in the *Monthly Notices*, vol. lvi. p. 11, and are deduced from the measurements of solar photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn, India, and at the Royal Alfred Observatory, Mauritius.

Table I. gives the mean daily areas of umbræ, whole spots, and faculæ for each synodic rotation of the Sun in 1894; and Table II. gives the same particulars for the entire year 1894, and the five preceding years for the sake of comparison. The areas are given in two forms. First, projected areas—that is to say, as seen and measured on the photographs—these being expressed in

millionths of the Sun's apparent disc; and next, areas as corrected for foreshortening, the areas in this case being expressed in millionths of the Sun's visible hemisphere.

Table III. exhibits for each rotation in 1894 the mean daily area of whole spots, and the mean heliographic latitude of the spotted area, for spots north, and for spots south, of the equator, together with the mean heliographic latitude of the entire spotted area, and the mean distance from the equator of all spots; and Table IV. gives the same information for the year as a whole, similar results from 1889 to 1893 being added as in the case of Table II. Tables II. and IV. are thus in continuation of the similar tables for the years 1874 to 1888, on pp. 381 and 382 of vol. xlix. of the *Monthly Notices*.

The rotations in Table I. and Table III. are numbered in continuation of Carrington's series (Observations of Solar Spots made at Redhill, by R. C. Carrington, F.R.S.), No. 1 being the rotation commencing 1853 November 9. The assumed prime meridian is that which passed through the ascending node at mean noon on 1854 January 1, and the assumed period of the Sun's sidereal rotation is 25·38 days. The dates of the commencement of the rotations are given in Greenwich civil time, reckoning from mean midnight.

TABLE I.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.		
			Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
	days							
538	1893 Dec. 16·75	25	529	2785	1932	390	2119	2186
539	1894 Jan. 13·09	27	383	2174	1133	268	1553	1274
540	Feb. 9·43	28	319	1794	1692	234	1329	1874
541	Mar. 8·76	27	256	1390	1212	167	933	1297
542	Apr. 5·06	27	356	1949	1705	272	1518	1919
543	May 2·31	28	456	2417	1942	355	1870	2115
544	May 29·53	27	515	2651	1745	380	2034	1988
545	June 25·73	27	420	2315	2353	299	1695	2626
546	July 22·94	27	372	2093	1453	259	1477	1628
547	Aug. 19·16	28	201	1022	1560	142	736	1774
548	Sept. 15·42	27	331	1785	1867	230	1266	2110
549	Oct. 12·70	27	155	776	1990	120	617	2371
550	Nov. 9·00	28	186	1018	1534	136	773	1698
551	Dec. 6·31	27	188	1164	1613	140	902	1834

TABLE II.

Year.	No. of Days on which Photographs were taken.	Mean of Daily Areas.			Corrected for Foreshortening.		
		Umbræ.	Projected Whole Spots.	Faculæ.	Umbræ.	Whole Spots.	Faculæ.
1889	360	17·9	103	107	13·1	78·0	131
1890	361	21·3	133	273	15·5	99·4	304
1891	363	120	745	1322	86·2	569	1412
1892	362	255	1596	3230	186	1214	3270
1893	362	327	1983	2287	234	1464	2404
1894	364	317	1728	1666	231	1282	1877

TABLE III.

No. of Rotation.	Date of Commencement of each Rotation.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
	days			°		°	°	°
538	1893 Dec. 16·75	25	585	+13·85	1534	−10·74	− 3·95	11·60
539	1894 Jan. 13·09	27	490	+ 9·96	1063	−11·71	− 4·87	11·15
540	Feb. 9·43	28	236	+12·73	1094	−26·40	−19·47	23·98
541	Mar. 8·76	27	790	+14·55	142	− 9·85	+10·83	13·83
542	Apr. 5·06	27	685	+16·44	833	−19·50	− 3·29	18·12
543	May 2·31	28	419	+14·80	1451	−14·66	− 8·06	14·69
544	May 29·53	27	955	+11·59	1080	−14·27	− 2·14	13·01
545	June 25·73	27	885	+10·94	810	−13·51	− 0·74	12·17
546	July 22·94	27	1052	+10·29	425	−14·33	+ 3·21	11·45
547	Aug. 19·16	28	465	+10·73	271	−12·94	+ 2·02	11·54
548	Sept. 15·42	27	405	+12·06	862	−12·08	− 4·36	12·07
549	Oct. 12·70	27	344	+11·74	273	−12·04	+ 1·21	11·87
550	Nov. 9·00	28	290	+11·80	483	−16·17	− 5·69	14·53
551	Dec. 6·31	27	183	+12·00	719	−16·28	−10·54	15·41

TABLE IV.

Year.	No. of Days on which Photographs were taken.	Spots North of the Equator. Mean of Daily Areas.	Spots North of the Equator. Mean Heliographic Latitude.	Spots South of the Equator. Mean of Daily Areas.	Spots South of the Equator. Mean Heliographic Latitude.	Mean Heliographic Latitude of Entire Spotted Area.	Mean Distance from Equator of all Spots.
			°		°	°	°
1889	360	5·0	+ 7·26	73·0	−11·90	−10·68	11·61
1890	361	53·1	+22·20	46·3	−21·75	+ 1·73	21·99
1891	363	401	+20·49	169	−19·91	+ 8·52	20·31
1892	362	607	+15·09	607	−21·69	− 3·29	18·39
1893	360	517	+14·91	941	−14·26	− 3·93	14·49
1894	364	543	+12·31	739	−15·56	− 3·75	14·18

The principal features of the Sun-spot record for 1894, as brought out by the above tables, are :—

(1) A definite decrease in the mean daily areas of whole spots as compared with 1893 is shown, though this area was greater in 1894 than in 1892, and considerably greater than in 1883, the year of maximum in the preceding cycle.

(2) Faculæ have diminished in a yet higher ratio ; the decline in their case having set in strongly in 1893, a year earlier than with the spots, and having continued throughout 1894.

(3) Umbræ have shown hardly any decrease as compared with 1894.

(4) The decline as to whole spots has been limited to the southern hemisphere, the northern showing a slight recovery.

(5) But the southern hemisphere still remains the predominant one.

(6) Little change has taken place in the mean distribution of the spots in heliographic latitude, but the general trend of movement is still towards the equator.

(7) There is a slight reversal of this trend for the southern hemisphere considered separately, due chiefly to the great outburst of February 16 to March 1 in latitude $-32°$; but the movement towards the equator is very marked for the northern hemisphere.

(8) It may be added that no day in 1894 showed the Sun entirely free from spots.

Photographic Stellar Spectra of the Variable Star β Lyræ, and also of Types III. and IV. By F. McClean, M.A., LL.D., F.R.S.

The exceptional phenomena revealed in the spectrum of the variable star *β Lyræ* are well known, and hypotheses have been framed to account for them by Pickering and others.

The series of comparative photographs which accompany this paper (Plates 1 and 2) show distinctly the periodic variations of this spectrum. They extend from H_β to H. The negatives were taken during the autumn of 1895.

Pickering in 1891 identified the spectrum with hydrogen and the *Orion* stars. Lockyer in 1894 attributed the absorption spectrum to two stellar components, one resembling *Rigel* and the other *Bellatrix*. He found that the bright lines and the *Bellatrix* lines were displaced in the same direction, but not to the same extent.

On comparing the spectrum of *β Lyræ* with the spectra of other Helium stars, it appears that the nearest approach to it is the spectrum of *ζ Tauri*. The spectrum of this star has

therefore been mounted in conjunction with the series of *β Lyræ*. It will be seen that with small exceptions the whole of the principal absorption lines in the two spectra correspond. These lines also correspond, almost line for line, with the principal lines in the same portion of the spectrum of Clevèite Gas as determined by Runge and Paschen (*Astrophys. Journ.* Jan. 1896, see Note 2). The hydrogen lines and the K line are superadded. The absorption line, which appears most distinctly to shift its relative position, is the Helium line at w.l. 3964, close to H_ϵ. The curious effect of displacement and doubling seen in the Helium line at w.l. 4472 appears to be due to the alternate obscuration of this line and the adjacent iron (?) line at w.l. 4482, by the shift of the corresponding diffuse emission Helium line at w.l. 4472.

In mounting the photographs, the whole of the relative displacement has been given to the bright line spectrum, but of course this need not be the case. It appears, on the whole, as if the diffuse bright lines of the emission spectrum corresponded with the hydrogen lines and the principal Helium lines of the absorption spectrum.

On the seventh and the thirteenth days the two spectra appear nearly to correspond in position. At other times, from the thirteenth to the seventh day, the bright-line spectrum is displaced towards the red, and from the seventh to the thirteenth day towards the violet. There are however discrepancies in this general effect which it is difficult to reconcile.

The systematic classification of stellar spectra was established by Father Secchi in 1866 and 1867. The photographs which accompany this paper are included in his Types III. and IV. Stellar spectra of these types have been thoroughly investigated by Huggins, Dunér, Vogel, Lockyer, and others. Dunér's celebrated Memoir forms an exhaustive treatise on the subject.

The banded portions of these spectra, called "Dunér's Bands," are distinctly shown.

The photographs of Type III., in addition to the bands, show line absorption spectra in nearly all respects identical with Type II. (the solar type).

There is increased general absorption in the violet, and various groups of lines, due to calcium, manganese, and other substances, are intensified. The general character of the spectrum remains unchanged. The bands supervene gradually, and some of them can be recognised in spectra of Type II. The crucial band appears to be Band No. 5, which is only present in the characteristic spectra of this type. This band appears faintly on the transitional spectrum of *α Tauri* (*Aldebaran*), and the manner in which it there supervenes on the spectrum of Type II. appears to preclude the possibility of the adjacent bright band being other than an effect of contrast. The practical identity of the line absorption spectra of Types II. and III. indicates that the

transition from one to the other is due to the natural course of change in the condition of the stars themselves.

The stars of Type IV. are mostly below the 6th magnitude. Two different photographs are given of the star 152 Schjellerup of the 5½ magnitude. This is Secchi's "Superba." Two hours' exposure was required, which accounts for the exaggerated distortion due to the changing amount of refraction during exposure. The value of the faint details is enhanced by the correspondence of the two photographs. The presence of a line absorption spectrum is distinctly shown, and it appears to agree to a marked extent with the usual line spectrum of Types II. and III. There appears to be no trace of Dunér's Band, No. 5 of Type III. The inference seems to be that spectra of Type IV. arise from a natural course of change in these stars, passing directly from Type II. They are stars of Type II. become less luminous, but not different in kind.

It is well known that the "Dunér Bands" of Type IV. are due to the absorption of hydrocarbon, being the reverse of the emission spectrum of hydrocarbon gas.

Notes.

Note 1.—Photographs of *β Lyræ*.

		d	h			d	h
No. 1 from min.		0	6	No. 7 from min.		7	0
2	„	1	1	8	„	8	0
3	„	2	19	9	„	8	5
4	„	4	1	10	„	8	21
5	„	5	0	11	„	11	2
6	„	6	0	12	„	12	2

Comparison spectra, *β Orionis* and *ζ Tauri*.

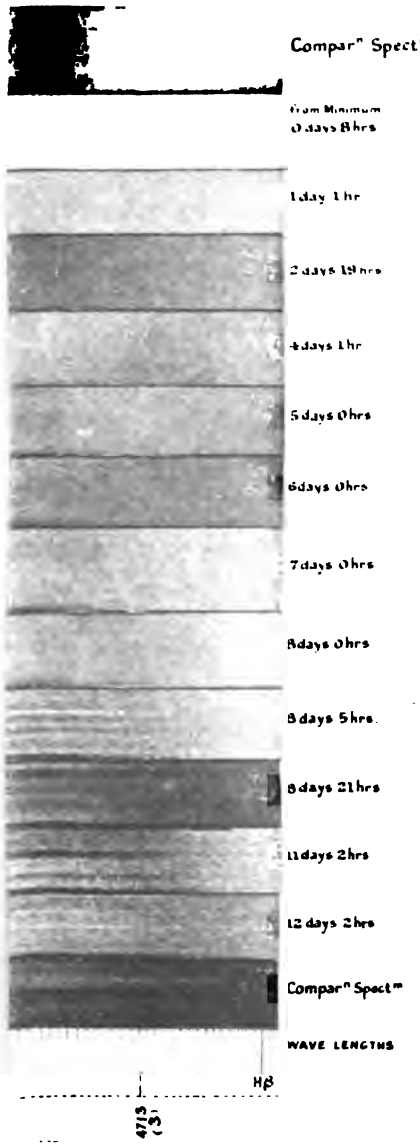
Note 2.—Principal lines in the spectrum of clevèite gas, from H_β to H_ζ Runge and Paschen, *Astrophys. Journ.* 1896 Jan. Lines of intensity 1 omitted.

Wave length	3889.	Intensity	10	Wave length	4144.	Intensity	2
„ „	3965.	„	4	„ „	4388.	„	3
„ „	4026.	„	5	„ „	4472.	„	6
„ „	4120.	„	3	„ „	4713.	„	3

Note 3.—Secchi, *Comptes Rendus*, 1866 Octobre 8; *Memorie della Società Italiana*, 1867, 1868.

Note 4.—Stellar spectra of Type III.—*o Ceti* (showing bright lines, H_γ and H_δ), *α Tauri*, *α Orionis*, *α Scorpii*, *β Andromedæ*, *α Ceti*, *δ Ophiuchi*, *μ Geminorum*, *δ Virginis*, *β Pegasi*, *α Herculis*. Not included, *γ Eridani* and *μ Ursæ Majoris*.

ζ β LYRA.



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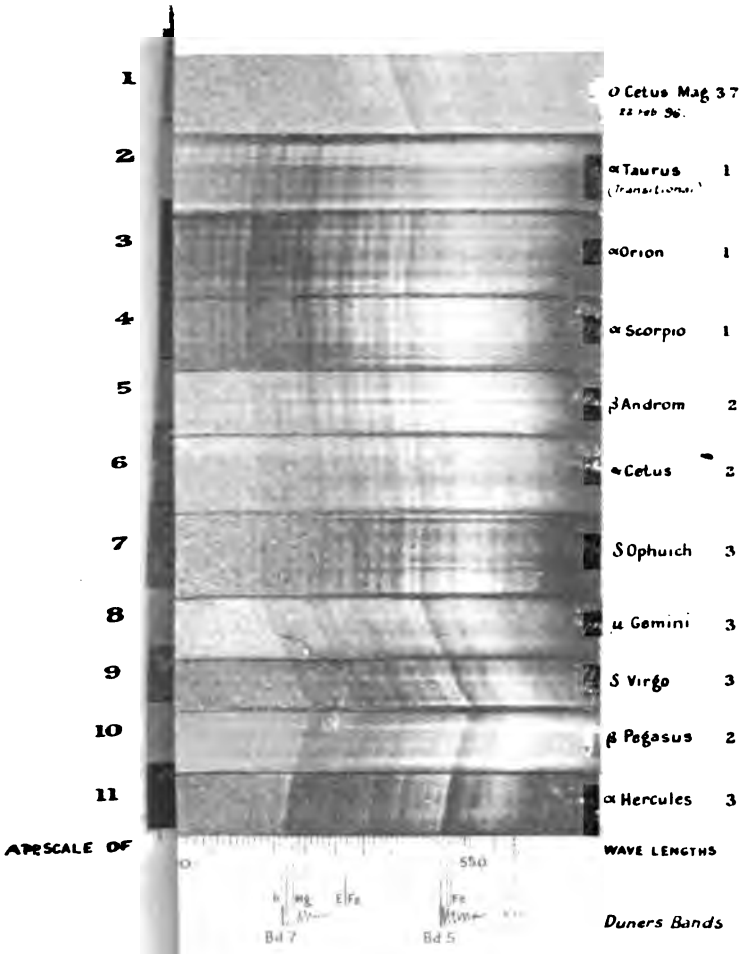
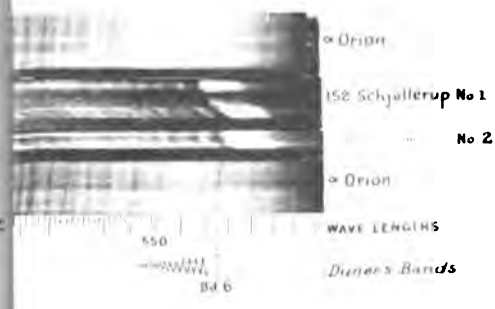
TYPE III.



TYPE IV



Note on the Effects of Distance upon the Spectra of Physical Clusters of Stars. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

I considered, in 1877, the nature of the spectra of physical clusters of stars of which the individual members were sufficiently near to each other, relatively to the distance of the stars generally, to sensibly influence—by their mutual gravitation and heating effects—the distribution of the coronal matter which surrounds an isolated star, such as our Sun. In the case of such a cluster, consisting of three, four, or any definite number of stars, the coronal matter would become distributed through a limited portion of space. I stated that in this case the brightness of the spectra of the individual stars would decrease in the proportion of the inverse square of the distance; but that such would not be the case with the spectrum of the sensibly continuous luminous surface formed by the gaseous corona. And that consequently, although in the case of such clusters at moderate distances we might, and should, observe directly the spectra of the individual stars forming the cluster, yet at greater distances the light thus received might become less than that received from the sensibly continuous gaseous envelope.

My views were objected to on the grounds that the light of the corona around each star would decrease in the same way as that of the individual stars; and such would have been the case, and the objection a fatal one to my views, if the coronal matter around each star of such a cluster remained isolated and not distributed over a finite space by the mutual actions of the individual stars of the system. But after I had called attention to the point that my reasoning applied to physical clusters with the necessary distributed gaseous matter over a limited space, no more was heard by me of this criticism.

But I have been surprised to read in Frost's English edition of Dr. Scheiner's *Treatise on Astronomical Spectroscopy*, p. 232, as follows:—

"This hypothesis has been criticised on various sides, and its principal fallacy may be easily seen. Stone overlooked the fact that the number of stars whose light enters the slit increases just in proportion as their brightness decreases."

Now what is here stated by the authors as a fact is certainly not true.

In the case of surfaces of sensibly continuous illumination the compensation mentioned is effective, but it would not be effective in the case of three, four, or any definite number of isolated stellar points.

It may perhaps save time to some who consult Frost's work if attention is called to an error in the numerical value assigned

to the constant number in Balmer's formula, which is given on p. 230.

The frequency

$$N = \frac{1}{\lambda}$$

is stated to be found for the hydrogen lines from the equation —

$$N = 2748 \cdot 13 (1 - 4m^{-2})$$

and a reference is given to the *Phil. Mag.* 1890. But I find that—

$$N = 2742 \cdot 625 (1 - 4m^{-2})$$

or

$$\lambda = 3646 \cdot 141 \frac{m^2}{m^2 - 4}$$

gives the standard wave lengths with much greater accuracy.

On the Comparison of Reflector and Portrait Lens Photographs.

By E. E. Barnard.

In the *Monthly Notices* for 1896 April Dr. Roberts has given a comparison of the photographic plates made with his 20-inch reflector, and with two portrait lenses of 3½ and 5 inches diameter. These small lenses have foci of 9·56 inches and 19·22 inches respectively, while the 20-inch reflector has a focus of 98 inches. At the close of his paper Dr. Roberts takes occasion to criticise several of my star photographs, now in the possession of the Royal Astronomical Society, which were made at Mount Hamilton with the 6-inch Willard lens of 31 inches focus.

These comparisons of the portrait lenses with the reflector might be objected to upon several grounds. First of all, the only claims of superiority that I know of which have been urged in favour of the portrait lens are its advantages, on account of small scale and wide field of view, in showing very large and faint nebulous areas, the phenomena of the tails of comets, and the structural forms of the Milky Way. In these special fields it is supreme, and likely to remain so until some better instrument than any hitherto used has been devised for this class of work.

The method of comparison by counting the number of stars shown on equal areas of the reflector and portrait lens plates is not only not the best one, but is very unfair to the short focus lens. On account of the smaller scale of the portrait lens, what will appear as several stars on the reflector plate will often coalesce into one star on the plates with the portrait lens, and for this reason a count of the stars, particularly with a long exposure, must necessarily be favourable to the larger instrument.

A fairer way, and one freer from error, would be to select regions free from bright stars, on a plate of sufficiently short exposure to make identification of the stars an easy matter, and then see if the faintest stars were wanting on the small plates. An estimate of the difference of magnitude between the faintest stars that are shown on the small plates and the faintest on the reflector plates, will tell more concerning the relative penetrating powers of the two instruments than all the counts of individual stars that could ever be made, and this is equally fair to the reflector and the portrait lens.

To further show the fallacy of the method of counting the stars in a test of this kind, it is only necessary to call attention to the fact that a very slight difference in the actual magnitudes of the smallest stars shown on the two plates may double or treble the number of stars revealed by the larger instrument. In the Milky Way this difference would be still more increased.

In reference to my photographs which Dr. Roberts mentions, I would say that there must have been an interchange of dates on the two positives of the neighbourhood of γ *Cassiopeiæ*, which were sent to the R.A.S. The one he speaks of as having been made 1894 February 2, with three hours' exposure, can scarcely be the one he has examined, for on that plate γ *Cassiopeiæ* is 8° from the middle of the field, and at a point where all the small stars are defective from distortion. No one should attempt to count the stars under these conditions, and hence I assume this is really not the plate referred to (see note at end of this paper). There is another plate near the region of γ *Cassiopeiæ* which was made 1894 February 6, with $1^h\ 47^m$ exposure on a constantly thickening sky, which finally stopped the exposure. The effective exposure on this plate would be far less than this time, and I think an hour and a half would be a too liberal estimate of the equivalent time under ordinary conditions, and perhaps one hour would be nearer the mark. On this last plate γ *Cassiopeiæ* is about 4° from the centre; and in fairness no one ought to select such a position on a portrait lens plate for comparison with the central part of another picture. On this plate (assuming it is the one used by Dr. Roberts) he succeeded in counting 1,300 stars in an area of 2° square about γ *Cassiopeiæ* as a centre. In this same area he counted the following on his own plates with $2^h\ 12^m$ exposure :—

With 3½-inch lens, 1,080 stars.
With 5-inch lens, 2,610 stars.
With 20-inch reflector, 17,100 stars.

After seeing his article, I was curious to know how many stars were really shown on my plate, in the exact region examined by him. Over a glass positive from this negative I placed a square aperture 2° × 2° with γ *Cassiopeiæ* in the centre. On the positive was ruled a series of small squares to avoid confusion in the counting. This space was examined with a suitable magni-

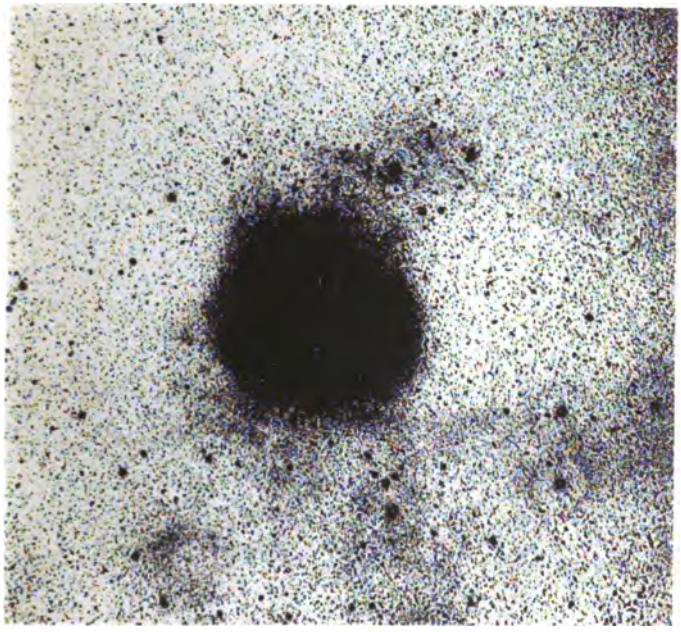
fying power, and the result was that 3,396 stars were counted where Dr. Roberts discovered only 1,300. This seems to me to speak very favourably for the performance of the Willard portrait lens under trying circumstances. The image of γ *Cassiopeiæ* on the original negative is round and sharp, and only 4″·5 in diameter. On his own plates Dr. Roberts found, with $2^h\ 12^m$ exposure, the image of γ *Cassiopeiæ* had the following diameters:—

With 3½-inch lens, 18″·7.
With 5-inch lens, 10″·2.
With 20-inch reflector, 16″·9.

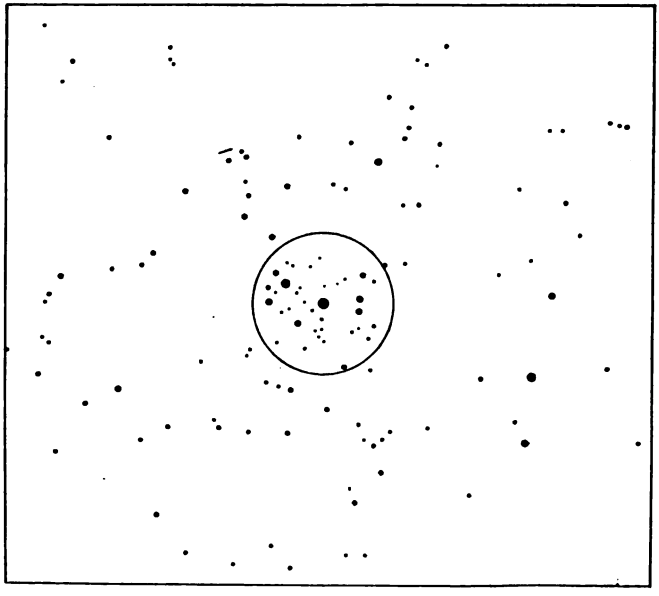
It would appear that these images are abnormally large compared with those of the Willard lens.

Dr. Roberts mentions the lack of details in the two fan-shaped nebulæ close to γ *Cassiopeiæ* which were discovered with the Willard lens. This was doubtless due to the short exposure and the thick sky. The night was not suited for the photography of nebulæ. In speaking of these two nebulæ Dr. Roberts says: "I may here state that the two fanlike nebulæ which have been referred to, were faintly shown on a photograph of the region of γ *Cassiopeiæ*, which was taken with the 20-inch reflector on 1890 January 17, but at that time I thought they were due to stains on the film." Considering the importance of these nebulæ, it is to be regretted that Dr. Roberts did not repeat his exposure to see if the markings were only stains on the plate. The discovery of these interesting objects might then have been credited to the 20-inch reflector. Referring to this same picture of 1890 January 17 in his book of celestial photographs, Dr. Roberts distinctly discredits the existence of any true nebulosity about γ *Cassiopeiæ*.

He has also taken occasion to notice two plates of the neighbourhood of the Pleiades made by me at Mount Hamilton. The first of these was given four hours' exposure 1893 December 1. Time has always been too precious to warrant the making of exposures on objects which were manifestly unsuited for my instrument, and those which had been successfully photographed elsewhere with instruments better adapted to the purpose. One of the objects thus recognised as beyond my reach was the Pleiades, and therefore I never made any photographs of that cluster to show the closer nebulosities which are mixed up with the brighter stars. Objects of this class belong entirely to large telescopes. The first of the photographs was made in the hope of showing certain vague nebulosities I had previously seen with the telescope north of the Pleiades. For this reason the cluster itself was placed some distance from the centre of the field, the suspected nebulous region being given preference of position. The positive of this plate sent to the R.A.S. was not sent in competition with photographs of the cluster made with more powerful telescopes, but simply to show the general appear-



EXTERIOR NEBULOSITIES OF THE PLEIADES.
E. E. BARNARD.



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ance of the stars in that part of the sky, and as a supplement to the one with two nights' exposure, on which the star images were not good. On this four-hour plate the Pleiades are 3° from the centre of the field, and therefore not in the best position to show the faintest stars in that vicinity. On this positive Dr. Roberts counted in a space 2° by 2°, with η central, 825 stars, against the following with 2^h 50^m exposure made at his observatory:—

With the 5-inch lens, 953 stars.
With the 20-inch reflector, 3,470 stars.

By the same method used with γ *Cassiopeiæ* and with η central, I counted in the same area 1,042 stars distinctly shown. Why he should find so few stars on my plates when so many exist, I would not attempt to explain. The image of η *Tauri* on the original negative is 3′·9 in diameter, and is round and sharp. Traces of the exterior nebulosities are shown on this plate on each side of the cluster, and this led me to place the Pleiades more central in the long exposure made afterwards.

The other photograph of this region was taken 1893 December 6 and 8, and the whole exposure was 10^h 15^m. The exposure was begun December 6, but the following night was cloudy, and the plate therefore lay in the camera from the 6th to the 8th. The camera box was of wood, which on Mount Hamilton is always subject to much change by shrinkage or expansion. Under these conditions it is really remarkable that after two entire days, one entire night, and parts of two other nights, it was possible to again so perfectly match the star images at the second exposure that it requires close examination to detect a slight overlapping of the star discs. With all these difficulties the picture admirably serves its purpose, since it was only intended to show the exterior nebulosities to which everything else was sacrificed. Dr. Roberts says of this picture, that the star images are elongated and overlapping; and he should have seen that it could not fairly represent a continuous exposure of $10\frac{1}{2}^h$. I fail, however, to see the force of his reasoning that because of these conditions, "some doubt would be cast on the reality of the distant nebulosity which is shown on the plate."

In reference to the slight elongation of the stars on this plate, mentioned by Dr. Roberts, where the plate was in the camera for over fifty hours, I think he can appreciate the difficulty of keeping the stars round even with short exposures, as will be seen by reference to his book of photographs, where quite a number of the pictures show defective star images. Plates 42 and 45 show strongly this elongation of the star images, and others in a lesser degree. Yet after all I fail to see how the slight elongation or overlapping of the stars in the Pleiades picture can have the least effect on the nebula itself, since the nebulosity is a surface and not a point of light. It would certainly get the full

benefit of the entire exposure, though the stars would not. On this plate the long exposure seems to have only slightly increased the diameters of the bright stars; the diameter of η measures 4′·5 against 3′·93 on the four-hour exposure. Both original negatives show considerable detail among the interior nebulosities, though the positives sent to the R.A.S. may not do so. The matter was not deemed of sufficient importance to make special positives for that purpose.

At a meeting of the B.A.A. on April 29, Dr. Roberts took a further opportunity to object to these star pictures, and is reported to have said the exterior nebulosities shown on my Pleiades photographs "were not nebulosity, and he made the assertion without fear of anyone proving the contrary." That these nebulosities exist as shown on my photographs there can be no doubt whatever. Indeed, it was the knowledge of their existence by visual observations alone that led me to make the photographs. The previous experience of Dr. Roberts with the diffused and faint nebulosity about 15 *Monocerotis* (*M. N.* vol. lvi. No. 2)—which was first shown to exist by the Willard lens—the discovery of which he at first discredited, might warrant some hesitation on his part in denying the existence of a similar region about the Pleiades.

In this connection I may mention that through the courtesy of Dr. Roberts I have a small glass positive of his photograph of the region of 15 *Monocerotis*. To my surprise, I find that his picture does actually show faintly this nebulosity, the existence of which he undertook to disprove by this very photograph. It is not shown so strongly as with the portrait lens, but all that is wanting to show it fairly well with his reflector is a somewhat longer exposure, and a larger plate to give more sky about it for contrast. The faint nebulosity will cover an entire plate of the size he now uses. I have compared his positive with an enlargement of my photograph of this region, not to count the stars, but to single out the faintest stars on his picture to see if they existed on mine. I was surprised to find how nearly my plate succeeded in showing every faint star on the other. There were some of his very faint stars not shown on my plate, but there would be scarcely half a magnitude between his faintest and my faintest. I am not sure but that fainter stars yet might have been shown on my plate were it not that the region possible for comparison on the two plates was covered with strong nebulosity on my plate in which very faint stars may have been lost.

Notwithstanding his condemnation of the faint nebulosities shown by portrait lenses to exist in certain parts of the sky, Dr. Roberts claims that his photographs of the dense globular clusters show essentially all these objects to be nebulous. As instances of this supposed nebulosity, he cites photographs of the following clusters, shown in his book of photographs of star clusters and nebulæ:—Messier 53, plate 29; M. 3, pl. 31; M. 5, pl. 33; M. 13, pl. 34; M. 12, pl. 35; M. 10, pl. 36;

M. 92, pl. 37; and M. 15, pl. 47. Speaking of these clusters, he says: "While the whole of the nebulosity has not been absorbed or utilised in the formation of the stars, some of the nebulosity, varying in extent and density, is shown on the photographs to be present in each cluster." He further endorses this statement in the notes in connection with the individual pictures.

If one examines the photographs referred to, the apparent nebulosity in most of them seems to be in all probability a photographic effect only, due to the crowding of the bright stars, combined with an unsteady atmosphere, and a lack of exact focus, and also further increased by the great enlargement from the originals. Take, for example, the cluster M. 3, which is perhaps the most nebulous-looking cluster in the entire book. If the small stars scattered everywhere on this plate are examined it will be seen that they are hazy and ill-defined like those of the same size in the cluster. These exactly resemble the photographic image of an out-of-focus star with too much subsequent enlargement. To prove the nebulosity of this cluster, Dr. Roberts compares this photograph with those of the very wide and loose clusters M. 11, pl. 40, and M. 37, pl. 18, and the double cluster of *Perseus*. In the latter the stars are widely separated, and there is consequently less chance of their running into each other through a lack of focus or by bad seeing. Such photographs cannot properly be used to prove the nebulosity of a closely packed globular cluster. If we look at the plate of M. 11, it will be seen that the small stars are ill-defined as if somewhat out of focus. A dense clustering of these stars would present a nebulous appearance, especially if the magnification was increased to correspond with that of the globular clusters. As a further example of this effect take plate 12, "Region of *Nova Aurigæ*." The stars scattered over this plate are hazy as though not exactly in focus. Compress these into a globular cluster, and increase the enlargement four times, and I think the result would be a splendid specimen of a "nebulous" globular cluster; and yet I believe Dr. Roberts has used this very picture to prove that *Nova Aurigæ* was not nebulous.

If we should treat the small stars shown in the plate of the nebula of *Andromeda* in this same manner, another "nebulous" globular cluster would be the result. Another good example is plate 49, where the small stars all over the plate are ill-defined and hazy. There are also other plates of this kind that might be mentioned—viz. plates 14 and 38, where an imperfection of focus produces a defective and hazy appearance in the stars which might well lead to apparently highly interesting results if combined into a globular cluster. I have examined these globular clusters in the sky with the most powerful telescopic means, and have found it impossible to decide whether they were nebulous or not when the seeing was at all indifferent; the bad seeing seemed to produce in them a haziness, much like nebulosity, by

the mixing of stray light. Under first-class conditions, however, when the air was very steady, the impression was that these clusters were free from true nebulosity.

A last word as to the relative value of the portrait lens and the reflector. The superiority of the one over the other will depend entirely on the object photographed. A short-focus portrait lens is only intended to show large structural details, such as the phenomena of comet tails, the great diffused nebulosities of the sky, the cloud-forms and details of the Milky Way, &c. When used for such work, no other form of instrument can equal it. When small details in limited areas are wanted, a larger instrument must be used, such for instance as Dr. Roberts's large reflector. For the small details in an object like the *Orion* nebula, it would be absurd to expect the best results from the small scale of a portrait lens. Yet the great curved nebula covering a large part of *Orion* is not only out of the reach of the large telescope, but it is best shown with an instrument beside which even the modest portrait lens is a giant. Still it is easy to imagine how poor these details shown in the great *Theta* nebula by a 20-inch reflector would appear, compared with those shown in another telescope with light and scale proportionally increased. If one compares the magnificent photograph of the cluster M. 13, in *Hercules*, made by Mr. W. E. Wilson, at Daramona, Ireland, with the photograph of the same object as shown in Dr. Roberts's book, with the same exposure, this difference will be more readily appreciated; and yet in this case the increase of aperture was only 4 inches.

In conclusion, let me say that specimens of my comet and Milky Way photographs, made with a portrait lens, are in the possession of the Royal Astronomical Society. An unprejudiced inspection of these will show their value to the science of astronomy. It must be understood, however, that they are to be looked at as pictures of the objects they represent, and are not to be examined with a microscope for details which in the nature of things it is impossible for them to show.

Kenwood Observatory, Chicago, Ills.:
1896 *June* 19.

P.S.—To see if any mistake had been made in dating the two positives of the region near γ *Cassiopeiæ* that are in the possession of the R.A.S., I sent tracings of them to Mr. Wesley, the Assistant Secretary of the R.A.S. He has kindly returned these tracings to me, since the above paper was written. He finds that they agree in date &c. with the positives, so that no mistake had been made. From this it appears that Dr. Roberts did actually use the 1894 February 2 photograph for comparison where the image of γ *Cassiopeiæ* is close to the edge of the plate and 8° from its centre, and where the small stars are either defective or entirely lost through distortion of the field!—E. E. B.

Observation of Comet f 1896 (*Perrine*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observation was made with the Sheepshanks' Equatorial, aperture 6·7 inches, by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power 55.

The initials C. D. are those of Mr. Davidson.

Greenwich Mean Solar Time.	Observer.	☄ − ✱ R.A.	Corr. for Refraction.	Log. Factor of Parallax.	☄ − ✱ N.P.D.	Corr. for Refraction.	Log. Factor of Parallax.	No. of Comps.	Apparent R.A. of ☄.	Apparent N.P.D. of ☄.	Comp. Star.
1896. d h m s		m s	s		′ ″	″			h m s	° ′ ″	
Nov. 4 8 54 8	C. D.	+0 2·12	0·00	9·5065	−6 3·9	−0·1	0·6971	6	20 18 47·09	66 11 26·7	*a*

Notes.

The observation is corrected for refraction, but not for parallax. It is also corrected for the error of inclination of the wires and for the motion of the comet.

The comet was extremely faint and difficult to observe.

Comparison Star.

Star's Name.	Assumed R.A. 1896·0.	Assumed N.P.D. 1896·0.	Authority.
	h m s	° ′ ″	
a Piazzi XX. 118	20 18 42·68	66 17 49·8	Berlin Astr. Gesell. Catalogue.

Royal Observatory, Greenwich:
1896 *November* 13.

Observations of Comet Perrine, 1896, November 2, at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100.

Date. 1896.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log. $(q \times \Delta)$.	Ref.
	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 4	7 5 17	21 58 19	R.	+3 44·17	+2 24·1	7	20 18 54·07	+0·1	9·225	66 7 43·9	2·8	0·634	(*a*)
5	7 38 56	22 36 0	W.	+6 7·13	+9 28·1	6	20 17 10·06	+0·1	9·354	66 57 42·1	3·0	0·662	(*b*)

Observers' Remarks.

(*a*) The coma can be traced over 1′·40″; the observed condensation, in the *north preceding* part of the coma, is distinct, though not stellar.

(*b*) The comet is very faint, but the nucleus appeared stellar at times of better definition; magnitude 12. Noise and the faintness of the object rendered the observations difficult.

Observers: W., Mr. Wickham; R., Mr. Robinson.

Assumed Places of Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	′	
(*a*)	20 15 7·64	+2·26	66 5 38·7	−18·8	Berlin, B., A. G., 7638
(*b*)	20 11 0·69	+2·24	66 48 32·2	−18·2	Berlin, B., A. G., 7591

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken from the *Circular der Central-Stelle*, November 7.

Radcliffe Observatory, Oxford: 1896 *November* 13.

Observation of Comet Perrine, 1895, IV., at the Radcliffe Observatory, Oxford.

(Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.)

The following comet observation was made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log $(q \times \Delta)$.	Ref.
1896.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Feb. 23	17 29 34	15 38 57	R.	−0 39·80	+0 59·4	10	19 46 33·91	−0·14	9·5079	89 38 11·4	3·1	0·8381	(*a*)

Observer's Remarks.

Comet much fainter than Perrine-Lamp (which was observed earlier), but easily seen. Coma 1′ in diameter. Nucleus 11 or 12 magnitude. The comparison star double, components sensibly equal, mag. 8; the second star observed.

Observer: Mr. Robinson.

Assumed Place of the Comparison Star.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	19 47 13·75	−0·04	89 36 59·7	+12·2	Mean Lalande, 37815; Schjellerup, 7651; Lamont, 22104

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distance, Δ, is taken from the *Astronomische Nachrichten*, No. 3327.

Radcliffe Observatory, Oxford: 1896 *November* 13.

Observations of Comets and Planets made with the 15-inch Dunecht Refractor and Wire Micrometer at the Royal Observatory, Blackford Hill, Edinburgh. By Dr. J. Halm.

(*Communicated by the Astronomer Royal for Scotland.*)

Comet 1896 I.

1896	M T. Edinburgh.	Δα. ♂ − ✱	Δδ.	No. of Comp.	α App.	Log pΔ.	δ App.	Log pΔ.	Reduction to App. Pl.	No. of Comp. Stars.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Mar. 12	9 21 5	+1 15·01	−2 1·8	18, 6	3 1 16·10	9·699	+48 36 27·2	0·659	−0·10 +17·2	1
15	12 14 32	+0 21·58	−7 39·1	6, 2	3 20 59·40	9·586	47 15 0·4	0·856	+0·06 +17.1	2
16	8 12 6	−1 35·75	−0 47·3	21, 7	3 25 21·86	9·649	46 54 59·0	0·549	+0·12 +17·1	3
16	8 57 14	−3 54·31	−0 59·1	12, 4	3 25 31·23	9·675	46 54 12·6	0·626	+0·12 +17·1	4
17	10 52 55	+3 51·44	−0 59·0	18, 6	3 30 44·86	9·664	46 29 10·2	0·782	+0·11 +16 8	5
18	10 24 49	+6 18·41	−7 2·2	15, 5	3 35 6·97	9·673	46 7 26·2	0 751	+0·11 +16·7	6
22	8 16 1	−1 51·57	−1 22·9	21, 7	3 49 44·26	9·634	44 50 30·8	0·583	+0·28 +16·5	7
				Comet 1896 III.						
Apr. 26	10 4 25	+2 8·62	+3 52·7	15, 5	3 18 38·97	9·496	+43 39 49·8	0 891	−0·22 + 9·8	8
27	9 31 25	+1 31·95	+3 34·9	18, 6	3 14 51·87	9·558	45 51 2·5	0·869	−0·29 + 9·7	9
29	11 1 12	−0 51·88	+6 40·7	21, 7	3 5 48·86	9·301	50 6 14·5	0·913	−0·45 + 9·5	10
May 9	10 18 54	−6 4·57	+0 48·4	12, 4	2 6 7·40	9·049	63 52 17·8	0·882	−1·42 + 4·6	11
10	10 20 11	+2 21·32	+7 59·5	18, 6	1 59 10·45	8 875	64 44 16·9	0·880	−1·52 + 3·2	12
19	11 29 46	−0 32·22	−2 14·9	3, 1	0 54 6·47	9·764*n*	69 55 20·4	0·794	−1·86 − 3·1	13
25	12 11 2	−5 44·69	−1 46·4	15, 5	0 11 6·21	9·985*n*	71 38 25·6	0·620	−1·57 − 6·4	14
29	12 55 14	−6 26·82	−4 36·0	6, 2	23 43 0·29	0·037*n*	72 19 12·8	0·404	−1·19 − 8·0	15
30	12 44 25	+6 33·45	+6 16 6	12, 4	23 36 13·19	0·040*n*	72 26 26 8	0·412	−0·93 − 9·4	16
31	11 53 42	+2 8·84	−9 39·9	18, 6	23 29 38·85	0·030*n*	72 32 33·3	0·523	−0·89 − 9·5	17

Planet (71) *Niobe.*

1896.	M.T. Edinburgh.	Δα. (♂ − ✱)	Δδ. (♂ − ✱)	No. of Comp.	α App.	Log $p\Delta$.	δ App.	Log $p\Delta$.	Reduction to App. Pl.	No of Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s ″	
Jan. 15	10 8 19	+1 45·65	...	24	8 54 30·98	9·428n	...	...	+2·29 ...	18
20	12 0 29	+2 54·23	−0 47·0	15, 5	8 48 27·66	8·887n	+25 36 42·3	0·651	+2·39 − 2·5	19
22	9 31 45	+0 0·21	−1 44·5	12, 4	8 46 6·98	9·428n	25 31 11·2	0·709	+2·42 − 2·6	20
22	9 48 49	+0 33·04	−6 15·5	8, 8	8 46 6·50	9·395n	25 31 13·8	0·699	+2·42 − 2·5	19
Feb. 1	9 57 40	+0 33·70	+6 51·5	18, 6	8 33 29·98	9·224n	24 55 44·8	0·678	+2·52 − 1·4	21
2	10 40 17	−0 43·80	+2 34·1	12, 4	8 32 12·49	8·985n	24 51 27·4	0·664	+2·53 − 1·4	21
3	8 35 58	+0 21·88	−2 18·5	18, 6	8 31 4·55	9·413n	24 47 30·2	0·712	+2·53 − 1·2	22
12	8 29 41	−0 32·88	−0 6·5	18, 6	8 20 24·82	9·321n	24 3 59·5	0·699	+2·54 − 0·3	23
					Planet (324)					
Jan. 20	10 16 26	−0 7·12	−0 52·2	6, 6	9 0 1·14	9·377n	+23 51 29·6	0·712	+2·33 − 3·5	24
20	10 39 17	−1 3·38	+6 57·7	18, 6	9 0 0·46	9·321n	23 51 32·2	0·701	+2·32 − 3·5	25
22	8 55 44	−2 18·21	+2 0·0	15, 5	8 57 50·08	9·491n	23 54 21·8	0·750	+2·36 − 3·5	24
Feb. 1	8 22 1	+0 19·74	−2 44·9	24, 8	8 46 30·16	9·470n	24 4 15·8	0·740	+2·51 − 2·5	26
2	10 1 34	−0 51·95	−2 12·2	15, 5	8 45 18·48	9·235n	24 4 48·5	0·689	+2·52 − 2·5	26
3	7 46 9	−1 52·07	−1 52·3	18, 6	8 44 18·37	9·501n	24 5 8·5	0·755	+2·53 − 2·4	26
10	7 18 6	+0 59·62	−5 1·7	15, 5	8 36 53·17	9·493n	24 5 3·8	0·751	+2·56 − 1·5	27
12	8 0 9	−1 1·69	−5 58·5	18, 6	8 34 51·87	9·418n	24 4 7·1	0·722	+2·57 − 1·4	27
17	8 32 50	−2 28·60	−3 18·6	15, 5	8 30 12·47	9·283n	23 59 57·8	0·695	+2·56 − 1·0	28
18	7 56 44	−3 19·10	−4 24·3	12, 4	8 29 21·97	9·366n	23 58 52·2	0·714	+2·56 − 0·9	28
21	8 27 26	+2 15·32	+4 47·0	18, 6	8 26 54·35	9·239n	23 54 48·3	0·690	+2·53 − 0·2	29

Planet (371)

1896.	M.T. Edinburgh. h m s	Δα. (⊙ − ✱) m s	Δδ. (⊙ − ✱) ′ ″	No of Comp.	α App h m s	Log pΔ.	δ App. ° ′ ″	Log pΔ	Reduction to App Pl. s ″	No of Comp. Star.
Jan. 22	11 8 46	+1 7·51	−6 30·6	6, 2	9 0 27·08	9·172n	+11 52 44·7	0·794	+2·14 − 2·8	30
Feb. 1	8 55 8	+0 51·37	+6 3·7	24, 8	8 51 8·50	9·397n	+12 7 28·5	0·808	+2·27 − 3·0	31
12	10 44 40	−0 25·62	−1 31·7	18, 6	8 40 51·66	8·587n	+12 28 1·6	0·783	+2·34 − 3·0	32

Planet (121) *Hermione.*

Feb. 18	8 39 11	+0 5·91	+5 23·9	8, 8	10 41 52·50	9·491n	+18 55 50·7	0·789	+2·49 −11·0	33

Planet (6) *Hebe.*

June 21	11 36 59	−0 42·39	+1 29·3	18, 6	16 27 46·70	9·009	− 0 40 53·4	0·866	+3·23 −11·7	34
25	12 11 41	+0 55·78	−7 22·9	15, 5	16 24 36·01	9·236	− 0 58 2·7	0·867	+3·27 −11·5	35
26	11 56 48	−4 27·30	+0 35·7	3, 1	16 23 52·08	9·203	− 1 2 43·1	0·868	+3·29 −11·2	36

Planet (287) *Nephthys.*

July 2	11 26 59	+1 24·20	+0 45·8	18, 6	20 19 48·88	9·249n	−11 19 29·6	0·895	+3·62 + 5·3	37
12	11 34 56	−1 29·66	−1 20·8	18, 6	20 11 44·35	9·016n	−12 22 1·9	0·911	+3·84 + 5·9	38
13	11 27 46	+2 22·83	+3 26·4	18, 6	20 10 51·22	9·030n	−12 28 58·3	0 911	+3·86 + 5·6	39
22	10 50 2	+0 24·54	+4 51·9	18, 6	20 2 34·27	8·998n	−13 36 48·2	0·915	+4·01 + 5·8	40
27	12 6 54	+2 32·39	−3 57·0	12, 4	19 57 53·13	8 700	−14 17 25·2	0·918	+4·07 + 5·3	41

Planet (386) 1894 *AY*.

1896.	M.T. Edinburgh. h m s	Δα. (♂ − ☉) m s	Δδ. (♂ − ☉) ′ ″	No. of Comp.	α App. h m s	Log $\rho\Delta$.	δ App. ° ′ ″	Log $\rho\Delta$.	Reduction to App. Pl. s	″	No. of Comp. Star.
July 13	12 46 6	+1 1·78	−5 43·5	18, 6	21 2 47·39	8·830*n*	+ 3 34 35·8	0·843	+3·43	+ 8·0	42
27	11 14 13	+2 57·65	−4 30·7	12, 4	20 53 42·81	9·027*n*	+ 2 12 35·9	0·852	+3·68	+ 9·8	43
Aug. 24	10 44 25	+1 14·91	+2 43·6	9, 3	20 34 0·52	8·562	− 2 31 0·4	0·876	+3·90	+11·5	44
25	9 54 32	−0 24·23	+3 59·8	18, 6	20 33 28·53	8·566*n*	− 2 42 32·6	0·877	+3·91	+11·6	45

Planet (304) *Olga*.

Aug. 24	11 24 13	−0 33·45	+5 19·0	18, 6	22 0 49·34	8·496*n*	− 7 8 33·4	0·895	+4·08	+18·4	46
25	9 19 8	−1 1 89	+1 2·0	15, 5	22 0 19·24	9·290*n*	− 7 26 9·8	0·889	+4·09	+18·4	47

Planet (61) *Danaë*.

Aug. 24	12 55 19	−2 47·59	−6 8·6	9, 3	22 0 19·78	9·022	−15 14 57·9	0·918	+4·26	+18·4	48
25	10 49 55	−3 45·74	−2 59·0	12, 4	21 59 21·63	8·876*n*	−15 11 48·3	0·920	+4·26	+18·4	48

Mean Places of Comparison Stars.

No.	R.A. 1896·0. h m s	Decl. 1896·0. ° ′ ″	Authority.
1	3 0 1·19	+48 38 11·8	A.G.Z. Bonn.
2	3 20 37·76	+27 22 22·4	,,
3	3 26 57·49	+46 55 29·2	,,
4	3 29 25·45	+46 54 54·6	,,
5	3 26 53·31	+46 29 52·4	,,
6	3 28 48·45	+46 14 11·7	,,
7	3 51 35·55	+44 51 37·2	,,
8	3 16 30·57	+43 35 47·3	,,
9	3 13 20·21	+45 47 17·9	,,
10	3 6 41·19	+49 59 24·3	,,
11	2 12 13·39	+63 51 24·8	A.G.Z. Hels. Gotha.
12	1 56 50·65	+64 36 14·2	,, ,,
13	0 54 40·55	+69 57 38·4	A.G.Z. Christiania.
14	0 16 52·47	+71 40 18·4	Bonn, Beob.
15	23 49 28·30	+72 23 56·8	Arg. Oeltzen.
16	23 29 40 67	+72 20 19·6	,,
17	23 27 30·90	+72 42 22·7	Bonn, Beob.
18	8 52 43·04	+25 48 58·0	Lalande.
19	8 45 31·04	+25 37 31·8	Bessel-Weisse.
20	8 46 4·35	+25 32 58·3	,,
21	8 32 53 76	+24 48 54·7	A.G.Z. Berlin B.
22	8 30 40·14	+24 49 49·9	,, ,,
23	8 20 55·16	+24 4 6·3	,, ,,
24	9 0 5·93	+23 52 25·3	,, ,,
25	9 1 1·52	+23 44 38·0	,, ,,
26	8 46 7·91	+24 7 3·2	,, ,,
27	8 35 50·99	+24 10 7·0	,, ,,
28	8 32 38·51	+24 3 17·4	,, ,,
29	8 24 36·50	+23 50 1·5	,, ,,
30	8 59 17·43	+11 59 18·1	Lalande.
31	8 50 14·86	+12 1 27·8	Bessel-Weisse.
32	8 41 14·94	+12 29 36·3	Lalande.
33	10 41 44·10	+18 50 37·8	A.G.Z. Berlin A.
34	16 28 25·86	− 0 42 11·0	Bessel-Weisse.
35	16 23 36·96	− 0 50 28·3	Bonn, Beob.
36	16 28 16·09	− 1 3 7·6	½ (Schj. + Gött.).
37	20 18 21·06	−11 20 20·7	Bessel-Weisse.

No.	R.A. 1895·0. h m s	Decl 1896·0. ° ′ ″	Authority.
38	20 13 10 17	−12 20 47·0	Bessel-Weisse.
39	20 8 24·53	−12 32 30·3	Lamont.
40	20 2 5·72	−13 41 45·9	Bessel-Weisse.
41	19 55 16·67	−14 13 33·5	„
42	21 1 42·18	+ 3 40 11·3	A.G.Z. Albany.
43	20 50 41·48	+ 2 16 56·8	„
44	20 32 41·71	− 2 33 55·5	Lamont.
45	20 33 48 85	− 2 46 44·0	Bessel-Weisse.
46	22 1 18 71	− 7 14 10·8	„
47	22 1 17·04	− 7 27 30·2	„
48	22 3 3·11	−15 9 7·7	Argel. Zonen.

Notes.

March 16.—Comet faint; clouds.
March 22.—Comet very faint; moonlight.
April 29.—Comet circular, with nucleus of about 10th magnitude.
May 9.—Observation interrupted by clouds. May 19.—As on May 9.
May 25.—Comet exceedingly faint, scarcely visible. The same for all the following observations of this comet.
May 31.—Possibly the M.T. of this observation is 10 min. too late.

Observations of Phenomena of Jupiter's Satellites at Windsor, New South Wales, in the Year 1896. By John Tebbutt.

Day of Obs. 1896.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *N. Almanac.* h m s
Jan. 22	II.	Occ. D.	First contact	4½ in.	120	23 44 31	
22	II.	Ecl. D.	Last seen	,,	,,	23 47 11	23 46 36
26	I.	Tr. Ingr.	Ext. contact	8 in.	138	23 58 5	
27	I.	,,	Bisection	,,	,,	0 0 30	
27	I.	,,	Int. contact	,,	,,	0 2 24	
27	I.	Ecl. R.	First seen	4½ in.	120	23 29 57	23 29 33
Feb. 3	I.	Occ. D.	First contact	,,	,,	22 47 52	
3	I.	,,	Bisection	,,	,,	22 50 21	22 50
3	I.	,,	Last seen	,,	,,	22 52 21	
4	I.	Ecl. R.	First seen	8 in.	90	1 23 50	1 24
4	I.	,,	Full brightness	,,	,,	1 26 35	
18	I.	Tr. Ingr.	Ext. contact	,,	300	23 39 2	
18	I.	,,	Bisection	,,	,,	23 40 41	23 39
18	I.	,,	Int. contact	,,	,,	23 42 31	
19	I.	Ecl. R.	First seen	,,	138	23 41 48	23 42 7
19	I.	,,	Full brightness	,,	,,	23 46 3	
26	I.	Occ. D.	First contact	,,	,,	22 31 25	
26	I.	,,	Bisection	,,	,,	22 33 15	22 32
26	I.	,,	Last seen	,,	,,	22 34 30	
26	III.	Ecl. R.	First seen	,,	,,	23 41 4	23 41 46
26	III.	,,	Full brightness	,,	,,	23 46 28	
27	I.	,,	First seen	,,	,,	1 36 52	1 37 3
27	I.	,,	Full brightness	,,	,,	1 40 9	
Mar. 3	II.	Tr. Egr.	Bisection	4½ in.	120	21 17 7	21 21
3	II.	,,	Ext. contact	,,	,,	21 20 32	
4	III.	Occ. D.	First contact	,,	...	20 22 28	
4	III.	,,	Bisection	,,	...	20 25 57	20 26
4	III.	,,	Last seen	,,	...	20 28 47	
5	III.	Occ. R.	First seen	8 in.	138	0 0 2	
5	III.	,,	Bisection	,,	,,	0 1 17	0 5
5	III.	,,	Last contact	,,	,,	0 2 47	
5	III.	Ecl. D.	Last seen	,,	,,	0 11 18	0 10 39

Day of Obs. 1896.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *N. Almanac.* h m s
Mar. 5	I.	Occ. D.	First contact	8 in.	230	0 17 50	
5	I.	,,	Bisection	,,	,,	0 19 44	0 19
5	I.	,,	Last seen	,,	,,	0 21 20	
5	I.	Tr. Ingr.	Ext. contact	,,	138	21 40 2	
5	I.	,,	Bisection	,,	,,	21 42 2	21 38
5	I.	,,	Int. contact	,,	,,	21 43 21	
5	I.	Tr. Egr.	Int. contact	,,	,,	23 54 55	
5	I.	,,	Bisection	,,	,,	23 56 59	23 58
5	I.	,,	Ext. contact	,,	,,	23 59 24	
6	I.	Ecl. R.	First seen	,,	74	22 0 31	22 0 50
6	I.	,,	Full brightness	,,	,,	22 4 15	
10	II.	Tr. Egr.	Bisection	,,	,,	23 41 4	23 44
10	II.	,,	Ext. contact	,,	,,	23 43 48	
11	IV.	Ecl. R.	First seen	,,	,,	0 23 58	0 27 44
11	IV.	,,	Full brightness	,,	,,	0 31 55	
15	III.	Shd. Egr.	Int. contact	,,	168	21 40 56	
15	III.	,,	Half off	,,	,,	21 46 0	21 53
15	III.	,,	Last seen	,,	,,	21 48 29	
19	II.	Ecl. R.	First seen	,,	112	23 20 11	23 20 21
19	II.	,,	Full brightness	,,	,,	23 23 53	
20	I.	Tr. Ingr.	Ext. contact	,,	168	1 17 14	
20	I.	,,	Bisection	,,	,,	1 18 59	1 17
20	I.	,,	Int. contact	,,	,,	1 21 29	
20	I.	Occ. D.	First contact	,,	,,	22 22 34	
20	I.	,,	Bisection	,,	,,	22 24 36	22 26
20	I.	,,	Last seen	,,	,,	22 27 0	
22	III.	Tr. Egr.	Int. contact	,,	,,	21 5 19	
22	III.	,,	Bisection	,,	,,	21 7 39	21 13
22	III.	,,	Ext. contact	,,	,,	21 12 13	
Apr. 5	I.	Occ. D.	First contact	,,	,,	20 34 52	
5	I.	,,	Bisection	,,	,,	20 37 26	20 38
9	III.	Ecl. D.	Began to fade	,,	74	20 5 25	
9	III.	,,	Last seen	,,	,,	20 10 58	20 9 8
12	I.	Occ. D.	First contact	,,	168	22 28 12	
12	I.	,,	Bisection	,,	,,	22 31 37	22 32
12	I.	,,	Last seen	,,	,,	22 32 57	
13	II.	Ecl. R.	First seen	,,	,,	20 22 40	20 23 3

Day of Obs. 1896.	Satellite.	Phenomenon.	Phase.	Aperture of Telescope.	Mag. Power.	G.M.T. of Observation. h m s	Mean Time of *N. Almanac.* h m s
Apr. 13	II.	Ecl.R.	Full brightness	8 in.	168	20 26 56	
13	I.	Shd. Ingr.	First contact	,,	,,	21 4 20	
13	I.	,,	Half on	,,	,,	21 6 50	21 6
13	I.	,,	Int. contact	,,	,,	21 8 29	
13	I.	Tr. Egr.	Int. contact	,,	,,	22 5 15	
13	I.	,,	Bisection	,,	,,	22 8 9	22 9
13	I.	,,	Ext. contact	,,	,,	22 10 49	
14	I.	Ecl. R.	First seen	,,	,,	20 35 6	20 35 13
14	I.	,,	Full brightness	,,	,,	20 37 54	
16	III.	Occ. R.	Last contact	,,	,,	22 28 51	22 33
18	II.	Tr. Ingr.	Int. contact	,,	,,	22 44 45	22 43
21	I.	Ecl. R.	First seen	,,	74	22 30 33	22 30 42
21	I.	,,	Full brightness	,,	,,	22 33 9	
28	I.	Occ. D.	First contact	,,	300	20 49 19	
28	I.	,,	Bisection	,,	,,	20 51 34	20 52
28	I.	,,	Last seen	,,	,,	20 52 49	
29	I.	Tr. Egr.	Bisection	,,	138	20 27 3	20 28
29	I.	,,	Ext. contact	,,	230	20 29 53	
May 6	I.	,,	Int. contact	,,	168	22 20 44	
6	I.	,,	Bisection	,,	,,	22 23 54	22 24
6	I.	,,	Ext. contact	,,	,,	22 25 48	
7	I.	Ecl. R.	First seen	,,	,,	20 50 25	20 50 32
7	I.	,,	Full brightness	,,	,,	20 53 53	
11	III.	Tr. Ingr.	Ext. contact	,,	132	21 11 6	
11	III.	,,	Bisection	,,	,,	21 14 21	21 14
11	III.	,,	Int. contact	,,	,,	21 18 15	
16	IV.	Ecl. D.	Began to fade	,,	168	19 59 54	
16	IV.	,,	Last seen	,,	,,	20 7 10	20 3 53
29	III.	Occ. D.	First contact	,,	,,	19 41 52	
29	III.	,,	Bisection	,,	,,	19 46 11	19 46
29	III.	,,	Last seen	,,	,,	19 48 26	
29	II.	,,	First contact	,,	,,	20 8 23	
29	II.	,,	Bisection	,,	,,	20 10 12	20 10
29	II.	,,	Last seen	,,	,,	20 12 17	
29	I.	Tr. Ingr.	Ext. contact	,,	,,	20 28 14	
29	I.	,,	Bisection	,,	,,	20 30 59	20 28
29	I.	,,	Int. contact	,,	,,	20 33 23	

In addition to the preceding observations the following times were noted, when the centres of certain objects were on the central meridian of the planet :—

Day of Obs. 1895	Object.	Aperture of Telescope.	Mag. Power.	G.M.T. h m s
Mar. 3	Shadow of Satellite II.	4½ in.	120	21 34 15
5	„ „ I.	8 in.	138	23 39 17
11	„ „ II.	„	168	0 4 15
29	Satellite III.	„	„	23 9 32
Apr. 13	Shadow of Satellite I.	„	„	22 9 18
29	„ „ I.	„	138	20 25 4
May 6	„ „ I.	„	168	21 20 14
24	Satellite IV.	„	„	20 4 1

Notes.

January 22.—Sky brilliantly clear, but Moon present; the satellite began to fade in eclipse when in contact with the limb.

January 26 and 27.—Images steady and definition pretty good for the transit ingress. Sky clear, but bright Moon and images tremulous and badly defined at the eclipse. The satellite was suspected 9·5 seconds earlier, and came out very close to the limb.

February 3.—Images steady and pretty well defined.

February 4.—Sky beautifully clear and definition excellent. When first seen the satellites are usually copper-coloured specks but on this occasion the satellite was first seen as a minute silvery speck close to the limb.

February 18.—Definition pretty good.

February 19.—Sky clear, but images slightly boiling.

February 26.—Images tremulous and not well defined at the occultation. Sky clear and images pretty well defined at the eclipse. The Moon was not far from the planet, and the time of first seeing is considered rather late.

February 27.—Sky beautifully clear, but Moon present.

March 3.—Planet boiling at internal contact; definition better at the other phases. The transit of the shadow of II. across the central meridian was estimated.

March 4.—Observation immediately after sunset.

March 5.—Sky clear and steadiness and definition pretty satisfactory at the occultation reappearance and eclipse disappearance. The satellite was very small at reappearance from occultation and immediately began to fade in eclipse. It was suspected 8 seconds after the recorded time of last seen. Steadiness and definition satisfactory at the occultation disappearance, and pretty satisfactory at the transit ingress. At the meridian transit of the shadow of I. and the transit egress of I. these conditions greatly improved. The transit of the shadow of I. was estimated.

March 6.—Sky clear and objects pretty steady and well defined.

March 10.—Good definition.

March 11.—The transit of the shadow of II. was observed by means of the micrometer threads. Sky very clear and definition good at the eclipse reappearance; the satellite came out close to another.

March 15.—Good definition.

March 19.—Planet occasionally dimmed by light clouds, but it shone bright and clear at the critical time. The satellite came out close to the first.

March 20.—Images tremulous and badly defined at the transit ingress, more particularly at the internal contact. The definition for the first two phases of the occultation disappearance was pretty good, but not for the last.

March 22.—Images steady and well defined and observations pretty good.

March 29.—The transit of III. over the central meridian was observed by means of the micrometer threads. The satellite was seen as a dark spot. A dark spot on the planet itself was observed to cross the meridian eight minutes later, and of the two objects the satellite was the darker.

April 5.—Definition not good and images tremulous.

April 9.—Beautifully clear, but twilight pretty strong. The time of beginning to fade was unusually well observed by comparison with another satellite.

April 12.—Definition not good, and last phase very difficult of observation.

April 13.—Sky clear, but definition not good. Satellite II. was suspected five seconds earlier than the recorded time. The transit of the shadow of I. across the central meridian was determined by estimation only.

April 14.—Sky beautifully clear and definition pretty good.

April 16.—Sky beautifully clear and definition pretty good; observation pretty accurate.

April 18.—Definition remarkably good.

April 21.—Sky beautifully clear, but images tremulous and ill-defined. The satellite was suspected four seconds before the recorded time.

April 28.—Good definition, except at final disappearance, when the limb was disturbed.

April 29.—The transit of the shadow was observed by means of the micrometer threads.

May 6.—The transit of the shadow was observed by estimation only. The definition was very bad at the transit of I., and the observations are therefore very unsatisfactory.

May 7.—Sky clear and steadiness and definition pretty satisfactory. The satellite was suspected ten seconds earlier than the recorded time.

May 11.—Images very tremulous and ill-defined and the times very unsatisfactory.

May 16.—Satellite suspected to be fading $1^m\ 20^s$ earlier than the recorded time. Sky beautifully clear, but twilight had scarcely disappeared. Images steady and well defined and observation of final disappearance good.

May 24.—The satellite was watched at intervals from $19^h\ 22^m$ to $21^h\ 23^m$ and found to be perfectly black—as black, indeed, as I have ever seen a shadow of a satellite. Neither the ingress nor the egress could be observed, and the transit across the central meridian was determined by estimation. The satellite differed in its appearance from the shadows in that it seemed to be in space between the observer and the surface of the planet.

May 29.—Bad definition throughout.

An occulting bar was not employed in the eclipse observations. The times given are the Windsor mean times of observation diminished by $10^h\ 3^m\ 20^s$ and entered to the nearest second. The observations of full brightness in the eclipses are at the best only roughly approximate. In determining these times the increasing light of the satellite was repeatedly compared with the other visible satellites.

Private Observatory, Windsor, N.S. Wales:
1896 *September* 5.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. DECEMBER 11, 1896. No. 2

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

George Alexander Sime Atkinson, 238 Newport Road, Cardiff, South Wales; and
John Burt Trivett, Trigonometrical Survey of New South Wales, Sydney, N.S. Wales, Australia,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election, the name of the proposers from personal knowledge being appended:—

George Banks, 4 John Street, Bedford Row, W.C. (proposed by C. A. Taylor);
John Charles Clancey, F.R.G.S., F.S.I., Assistant Director of Land Records and Agriculture, Burma, 7 Grafton Square, Clapham Common, S.W. (proposed by John Coles);
William Fraser Doak, M.A., Assistant, *Nautical Almanac* Office, 3 Verulam Buildings, Gray's Inn, W.C. (proposed by A. M. W. Downing);
Rev. Edward Spry Leverton, M.A., School House, Kirkham, Lancashire (proposed by Edwin Dunkin);
Ernest Frederick John Love, M.A., Lecturer in Physics in the University of Melbourne (proposed by Sir R. S. Ball);

William Arthur Smith, Merchant, 74 Hagley Road, Edgbaston, and 94 Charlotte Street, Birmingham (proposed by W. J. Lancaster); and

Edward Weldon, Merchant, 10 Morden Road, Blackheath, S.E. (proposed by H. P. Hollis).

Sixty-four presents were announced as having been received since the last meeting, including, amongst others:—

Sir G. B. Airy, Autobiography, presented by W. T. Lynn; W. Brennand, Hindu Astronomy, presented by R. Narayan Rai Bahadur; Charles Pritchard, Memoirs of his Life &c., presented by Miss Pritchard; Eclipse of 1860, M.S. observations, by C. Pritchard, and scrap-book of letters, drawings, &c., by J. Bonomi, presented by the executors of the late Professor Pritchard; G. V. Schiaparelli, Osservazioni del pianeta Marte Memorie IV., presented by the Author; Seven enlargements from lunar negatives taken at the Lick Observatory, presented by Dr. Weinek.

NOTICE TO FELLOWS.

THERE will be a Special General Meeting of the Society on 1897 January 8, at 9.45 P.M., after the Ordinary Meeting, to consider a proposal of the Council to alter Bye-laws 69 to 74 as follows :—

That Bye-laws 69 to 74 be altered by the addition of the word "gold" before the word "medal."

The Bye-laws in question at present read thus :—

EXTRACT FROM THE BYE-LAWS.

SECTION XVI.—*Of Awarding the Medal.*

69. No more than one medal shall be awarded or given during the course of any one year.

70. At the regular meeting of the Council, in the month of November in every year, the Council shall (prior to any other business) take into their consideration the propriety and expediency of awarding such medal ; and the name of every person who may be proposed and seconded as deserving the same shall be entered in the Minute-book.

71. Whenever more than one person shall have been proposed, the Council shall, at their regular meeting in December, select one of the persons so proposed to be submitted to the Council in January following on the question whether he shall or shall not receive the medal.

72. At the regular meeting of the Council in January following, the Council shall decide whether the nominee then before the Council shall or shall not receive the medal.

73. No medal shall be awarded in any other way than in the manner and at the time above prescribed ; nor unless three-fourths at least of the Members of the Council present shall agree thereto.

74. Notwithstanding the preceding Bye-laws, in cases where two or more persons have been jointly concerned in the production of any scientific treatise, or the carrying out of any research, work, or discovery, or have been the simultaneous but

independent authors of any such treatise, work, research, or discovery, the Council may, under these circumstances, receive the nomination of such two or more persons as joint recipients of the medal, and proceed thereupon in like manner as above mentioned with respect to the names of separate persons; and should the medal be ultimately awarded to such joint authors, workers, or discoverers, an impression of the medal shall be provided for and given to each of such joint recipients.

It will be seen that the above alteration will make it possible to award a Silver or Bronze Medal in addition to the Gold Medal. The Council now desire to award a Bronze Medal at intervals in accordance with the provisions of a Trust accepted by the Society in 1861 on terms which are specified in the extracts given below.

THE HANNAH JACKSON (*NÉE* GWILT) GIFT.

Extract from the Minutes of the Council of the Royal Astronomical Society, 1861 June 14.

The following proposal from Mrs. Hannah Jackson was received:—

"To the Royal Astronomical Society.

"I desire to give the sum of three hundred pounds stock now standing in my name in the books of the Bank of England to the intent that the same may be a reversionary gift into the names of the proper authorities for the time being of the Royal Astronomical Society of London, to be held upon trust for ever to pay and apply the dividends thereof, either annually or every two years, as they shall think fit, for the encouragement from time to time of any person writing the best astronomical work, or in any other way advancing astronomy, either by the invention of a new astronomical instrument or by the discovery of any new heavenly body. And I hereby desire that if, in the opinion of the said Society, the person writing such work or making such invention or discovery as aforesaid shall prefer the reward, they may choose the interest of the sum aforesaid in money or in a Gold Medal, and that the Gift shall be called the 'Hannah Jackson (*née* Gwilt) Gift.'

"I wish to receive the interest of the three hundred pounds stock without any difficulty during my life, but at the termination thereof, then to be held and applied as aforesaid for the purpose before named.

"Yours respectfully,
(Signed) "HANNAH JACKSON,
"*née* GWILT.

"P.S.—And I particularly wish that the gift may be completed without delay, as in a few weeks I propose going to Germany, and it will be very uncertain when I may return, and it is desirable to be done before then."

A discussion followed on the terms of Mrs. Jackson's proposal, and the form in which it could be received. The following resolutions were put:—

1. That in the event of Mrs. Jackson's offer being accepted the limit of the term of the accumulation of the interest be extended to seven years; proposed by Mr. Airy, seconded by Mr. Adams, and carried.

2. That it be permitted to apply the accumulated interest to the gift of a medal, or money, or of both; proposed by Mr. Airy, seconded by Mr. Walker, and carried.

3. That the objects of reward be the writing of an astronomical work or memoir, the invention or improvement of an astronomical instrument, the discovery of a new heavenly body, or the promotion in any other way of the science of astronomy; proposed by Mr. Airy, seconded by Mr. De la Rue, and carried.

4. That, subject to the above, the gift be accepted; proposed by Mr. Airy and seconded by Mr. Vignoles.

The following was proposed by way of amendment:—

That it be represented to Mrs. Jackson that it is desirable that such donations as hers should be as much as possible unfettered with conditions of application, and that Mrs. Jackson be asked if she would be willing to leave her fund as a special part of the funded property of the Society, with power to the Council to apply the interest as they may see fit from time to time; proposed by Mr. Carrington, seconded by Mr. Cayley, and negatived.

Resolution 4 was then put and carried unanimously.

Mrs. Jackson was then introduced to the Council, and the first three resolutions read and explained to her, when she gave her unqualified assent to the modifications introduced into her original proposal. The mode of transfer was arranged to be as follows:—Mrs. Jackson expressed her [intention] of directing her broker to transfer 300*l.* New 3 per cent. Stock now standing in her name in the books of the Bank of England to the Royal Astronomical Society, and to transmit the notice of the transfer thereof to the Treasurer of the Society, who would call at the Bank and accept the stock in the name of the Society, it being understood that a sum equal to the interest should be annually payable to Mrs. Jackson during her lifetime. Mrs. Jackson was also informed that the Council with pleasure acceded to her request that the *Monthly Notices* should be sent to her (gratis). She was further informed that her name would be enrolled in the list of benefactors.

Extract from the Annual Report of the Council, 1862 February (Monthly Notices, vol. xxii. No. 4).

The Council have to announce the receipt of a handsome reversionary gift. Mrs. Hannah Jackson has made over 300*l.* stock, reserving the dividends during her life, for the promotion of astronomy by rewards to be given in the name of "Hannah Jackson, *née* Gwilt." The conditions, including some slight modifications to which Mrs. Jackson at once consented on the suggestion of the Council, are as follows :—When the endowment takes effect, the accumulations of income, for any term not exceeding seven years, are, at the discretion of the Council, to be from time to time given in the form of a medal, or of money, or of both to the writer of any astronomical work or memoir, the inventor or improver of any astronomical instrument, the discoverer of any new heavenly body, or the promoter in any other way of the science of astronomy. The Council invite the Fellows to return thanks to Mrs. Jackson, not only for this very munificent gift, but for the judgment shown in allowing the mode of employment to be unfettered by any restrictions which might possibly diminish its utility.

Mrs. Jackson (or, as she styled herself latterly, Mrs. Jackson-Gwilt) died on 1893 December 1, and dividends were paid her up to that date. Since that time they have been accumulating, and there is now about 26*l.* in the treasurer's hands. Meanwhile the mode of awarding the Gift has been under consideration by the Council, and the following resolutions have been passed by them :—

1. That the award be called the "Hannah Jackson (*née* Gwilt) Gift."
2. That it consist of a money grant and a bronze medal.
3. That the design for the medal be a portrait of Sir William Herschel on the obverse, with allegorical design on the reverse, and be about 3 inches in diameter.
4. That the Gift be awarded at intervals of not less than three nor more than seven years.
5. That Bye-laws 69 to 74 be altered by the addition of the word "gold" before the word "medal."

It will be seen from the above extracts from the minutes of Council that—

Resolution 1 is necessary by the terms of the Trust, and

Resolution 2 was definitely contemplated at the time of acceptance of the Trust.

In accordance with Resolution 3, a design for a medal has been prepared by Miss Casella, and is now at the Society's rooms.

Resolution 4 is in accordance with the spirit of the resolution adopted at the time of acceptance of the Trust.

For Resolution 5 a General Meeting of the Society is necessary.

The proposed amendment of the Bye-laws is purely formal, no new principle being involved, since the general principle of the award of another medal was adopted by the Society in the adoption of the report of the Council for 1862, as quoted above. The amendment might have been considered at the Annual General Meeting in February next; but as it is proposed to make the first award of this Gift at that Annual Meeting, it is desirable to secure this alteration in the Bye-laws beforehand. Under these circumstances the Council resolved at their meeting on December 11 to call a Special General Meeting for 1897 January 8, as above, in accordance with Bye-laws 52, 49, and 51, which read as follows:—

52. Whenever the Council may think it advisable to propose the enactment of any new Bye-law, or the alteration or repeal of any existing Bye-law, they shall recommend the same to the Society at the Annual General Meeting next ensuing, or at a Special General Meeting convened for that purpose.

49. The Council may at any time call a Special General Meeting of the Society when it seems to them to be necessary.

51. A week's notice shall be sent to every Fellow residing in or near London of the time of any Special General Meeting, and of the business for which it is summoned, and no business shall be brought forward at such Meeting except what has been so notified.

E. W. Maunder,
H. H. Turner, } *Secretaries.*

The Total Solar Eclipse of 1896 *August* 9.

(*Note by the Secretaries.*)

A paper has been communicated to the Society by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Societies on observations of the above eclipse, and will appear in the *Memoirs*. The observations were made by Mr. E. J. Stone, Radcliffe Observer, who was enabled to occupy a station in Novaya Zemlya by the private enterprise and liberality of Sir George Baden-Powell, who had conveyed the observers there in his own yacht and at his own expense.

Mr. Stone read his paper to the meeting on December 11, and exhibited the photographic spectra of prominences which he had obtained with a wide slit. He further showed photographs of the spectrum of the outer corona taken during totality and up to 60 seconds afterwards (the general character of the spectrum remaining the same), and some outline drawings of portions of the corona.

After Mr. Stone had read his paper, Mr. W. Shackleton, who had also accompanied the expedition on the invitation of Sir G. Baden-Powell, showed some photographs of the spectrum of the chromosphere and inner corona, taken with an objective prism. One of these, taken just before totality, showed a series of bright lines in the positions of the Fraunhofer lines, and was presumably the spectrum of the so-called "reversing layer."

Sir George Baden-Powell had himself assisted Mr. Shackleton with the coronagraph during totality, exposing the plates on the Sun. He showed the series of photographs of the corona, and gave an account of the circumstances which led him to organise the expedition, and continued :—

"Perhaps I may say a word or two as to how we secured those wonderful astronomical results which Mr. Stone and Mr. Shackleton have so well described.

"They told you much, but on one important matter they were silent. They did not tell of the very arduous work through which they went—how they toiled in the face of cold, fog, rain, sleet, and wind to get the instruments set up, protected, and adjusted. Without all that devoted work and exposure there could and would have been no results.

"For instance, the Siderostat falsely worked quite well almost up to the time of totality, and then we could see, to our horror, on the ground glass in the coronagraph the image of the Sun travelling steadily off the field. Mr. Shackleton energetically attacked the clockwork adjustments, but still the image was refractory, and only just before totality did he say, 'Now she'll do!'

"Perhaps the happiest moment to me during the eclipse was after totality, and immediately all was bright and light again,

slipping in the ground glass and to my joy finding the image of the Sun still in the centre of the field.

"In going so far north I myself felt—perhaps because of the experiences of my respected uncle, Piazzi Smyth, on the Peak of Teneriffe—that much might be gained by this first setting up of really powerful instruments in so high a latitude, the atmosphere being, without doubt, *different* from that in lower latitudes, and especially in the tropics.

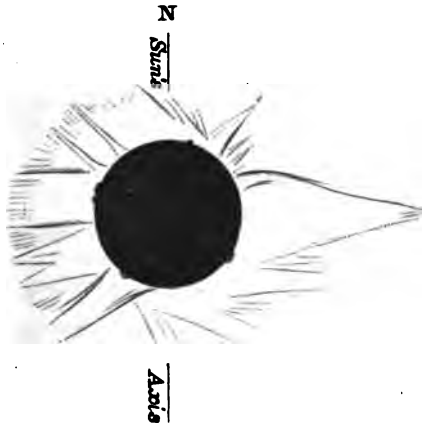
"I trust that our results, enhanced in value because the clerk of the weather saw fit to send clouds or rain to all the other stations scientifically occupied, will be of practical value in many ways, and especially, as it were, as stepping-stones between the photographic results first obtained in 1893 and those which will be secured in 1898."

Sir George Baden-Powell further expressed the opinion that, although he was glad to have been able to assist science by organising this expedition, it should not have been necessary to do so. Having had experience of the cost of such expeditions, he considered the amount placed at the disposal of the Committee was quite inadequate for the occupying of a proper number of stations; and he trusted it might be largely increased on future occasions. Should, however, the assistance of a yacht again be unavoidably necessary, he and Lady Baden-Powell would gladly again do all in their power, should they be free.

This generous offer was cordially acknowledged by the Fellows present.

Mr. W. H. Wesley, Assistant Secretary to the Society, who has had great experience in drawing different coronas, made the following remarks on the corona of 1896 :—

"The resemblance between the corona of 1896, as shown on



Outline of Corona of 1885.

the Novaya Zemlya photographs, and that of 1886 is very striking—closer, in fact, than that between any two coronas of different years that have yet been photographed. It may be interesting also to compare the corona of 1896 with that of 1885 (eleven years before), and I therefore give a rough outline which I sketched some years ago from negatives taken in New Zealand, which have never been published. The corona of 1885 does not appear so much like that of 1896, as the long extension on the north-west, shown in the latter year and in 1886, is in 1885 much nearer the Equator—forming, in fact, an equatorial extension. The sketch has been oriented from indications on the original; but should there be any mistake on this point, and the north pole of the Sun's axis in 1885 lie some 45° further west, the resemblance between the corona of that year and that of 1896 would be decidedly close.

Sketch of detail in the Corona of 1896.

"The corona photographs which have been taken in Novaya Zemlya are extremely beautiful, but, of course, no lantern slides can do justice to the original negatives. Some of the detail on the south-east quadrant appears to me of an unusual, if not unique, kind. This will be better understood from the rough sketch which I have made from a positive copy of one of the negatives; but a study of the originals would doubtless reveal much more than can be made out from the copy."

Comparison of the Sun's Longitudes for 1901, *computed from Newcomb's Tables of the Sun with those computed from Le Verrier's Tables.* By A. M. W. Downing, M.A., D.Sc., F.R.S.

The following comparison exhibits the corrections to apparent longitudes of the Sun (referred to the mean equinox of date), taken from Le Verrier's *Tables du Soleil*, deduced from the corresponding longitudes taken from Newcomb's Tables at eight-day intervals during the year 1901.

The large annual term appearing in the comparison is due mainly to the corrections for eccentricity and longitude of perigee, which (as is pointed out in *Monthly Notices*, vol. lvi. No. 2, page 69) amount to

$$+0''.40 \sin g - 0''.21 \cos g,$$

where g is the mean anomaly.

The outstanding residuals (after application of the above) are traceable to differences in the tables of perturbations.

Longitudes of Sun 1901.

Corrections to Le Verrier's Tables.

Day.	Correction.	Day.	Correction.
	"		"
Jan. 2	−0.86	July 5	+0.02
10	−0.64	13	−0.03
18	−0.59	21	−0.16
26	−0.69	29	−0.21
Feb. 3	−0.49	Aug. 6	−0.16
11	−0.39	14	−0.28
19	−0.40	22	−0.45
27	−0.38	30	−0.45
Mar. 7	−0.22	Sept. 7	−0.51
15	−0.14	15	−0.67
23	−0.20	23	−0.77
31	−0.10	Oct. 1	−0.72
Apr. 8	+0.01	9	−0.83
16	−0.01	17	−0.95
24	−0.04	25	−1.05
May 2	0.00	Nov. 2	−0.94
10	+0.08	10	−1.05
18	+0.06	18	−1.12
26	+0.01	26	−1.00
June 3	+0.13	Dec. 4	−0.92
11	+0.19	12	−0.95
19	+0.02	20	−0.95
27	−0.09		−0.72

Nautical Almanac Office:
1896 *December* 8.

On Systematic Errors in observing Right Ascensions of Nebulæ.

By J. L. E. Dreyer, Ph.D.

Although a great number of micrometer measures of nebulæ have been made during the last forty years, it has hitherto not been found feasible to combine the results into a general catalogue of accurate positions of nebulæ, owing to the systematic errors with which the observations of Right Ascension are more or less affected. Attention was first drawn to these errors by Julius Schmidt (*Astr. Nachr.*, No. 1463), who pointed out that Schönfeld's Right Ascensions, deduced from observations made with an annular micrometer, were systematically smaller than those found by himself with a similar micrometer, and, as was soon afterwards found, smaller than those of several other observers. In 1875, when the extensive and valuable series of filar-micrometer observations by Schultz had been published, I compared them with Schönfeld's, using only those objects which the two observers had compared with the same star, and I found from 113 objects the very pronounced difference Schönfeld I. – Schultz = $-0^s.34$. It appeared, furthermore, as already noticed by Schmidt, that the difference depended to a great extent on the degree of condensation of the objects. Dividing these into three classes according as they had a sharp nucleus, were fairly condensed or wanting any condensation, the difference was found to be *

I.	$\Delta\alpha \cos\delta = -0^s.15$	from 32	neb.
II.	$-0^s.39$	„ 53	„
III.	$-0^s.44$	„ 28	„

Shortly afterwards Schönfeld published his second series of measures, and, as might have been expected, the knowledge that he observed transits of nebulous objects too early led to a reduction of his personal error, the difference Schönfeld II. – Schultz being $= -0^s.15$. From this and the former difference there results Sch. I. – II. $= -0^s.19$, while the direct comparison between the two series gave $-0^s.21$, and an indirect comparison by means of Rümker's measures gave $-0^s.25$.†

Every series of observations which has been published since has confirmed the reality of these errors in the observed Right Ascensions, while differences in declination between various observers appear to be mere accumulations of accidental errors. Thus M. d'Engelhardt gives the following differences between

* *Vierteljahrsschrift d. Astr. Ges.*, vol. x. p. 72.
† *Ibid.*, vol. xi. p. 274.

his own measures and those of a number of other observers, which are in good accordance with the differences quoted above.*

		s		
Sch. I.	—Eng.	= −0·55	57	objects
Sch. II.	„	−0·39	60	„
Schultz	„	−0·21	70	„
Vogel	„	−0·18	50	„
Rümker	„	−0·27	31	„
Engelmann	„	−0·04	46	„
Auwers	„	−0·18	12	„
Oppolzer	„	−0·15	7	„
Ginzel	„	0·00	14	„
Dreyer	„	−0·47	22	„
Porter	„	−0·42	16	„
Weinek	„	+0·22	14	„
Gruss	„	−0·28	14	„
Kempf	„	−0·26	33	„

The mean of these fourteen equations is $-0^s\cdot23$, which tends to show that Schultz's measures are probably nearly free from these systematic errors. It will also be seen that my own error lies between those of Schönfeld's two series, as I have also found by direct comparison.†

		s		
Schönfeld	I. – Dreyer	= −0·11	27	neb.
„	II. „	= +0·04	38	„

In the summer of 1895 it occurred to me that it might be possible for an observer with a filar micrometer to determine his own personal error in a very simple manner. As there is every reason to believe that measures of difference of declination between a nebula and a star are practically free from systematic error (or at all events from any errors approaching in magnitude to those of the transit observations), a difference of Right Ascension between a nebula and an adjacent star might be measured both by transits and by the micrometer screw. Assuming, then, that the screw measures represented the true $\Delta\alpha$, the difference between them and the transits would directly give the error of the latter. In order to be perfectly free from bias I postponed the carrying out of this idea for some months, and abstained in the meanwhile from reading anything about measures of nebulæ. The reduction of the observations, and even the copying of them

* *Observations Astronomiques*, t. iii. p. 28.
† *Trans. Royal Irish Acad.*, vol. xxx. p. 522.

from the rough note-book into the volume of refractor observations, was also deferred until the final close of the series of measures; and, as I had even forgotten the signs of the differences between other observers and myself, I feel perfectly convinced that the results of these measures are altogether free from any conscious bias.

The observations given in the following table were made with the 10-inch refractor and the same filar micrometer with which my previous measures were taken. T is the $\Delta\alpha$ (nebula minus star) observed by transits with eye and ear, from ten to sixteen single-wire transits being generally taken; M is the same $\Delta\alpha$ measured four or five times with the screws while the clock was carrying the telescope along. In the column "Cond." the nebulæ are classified according to whether they have a fairly sharp nucleus (1), or are more or less devoid of condensation (2). The column "Star" gives the magnitude of the comparison star and its place relative to the nebula. The $\Delta\delta$ was generally small. I give the results in full, as they may eventually be of use in determining proper motions of the objects.

G.C.	Date.	T.	M.	M−T.	Cond.	Star.	Notes.
		s	s	s			
307	4 1 96	+20·12	+20·13	+0·01	1	10·5, n p	Good object.
1904	1 4 96	+12·99	+13·42	+0·43	2	12, s p	
2038	1 4 96	−34·93	−35·43	+0·50	1	11, f	
2041	1 4 96	− 6·02	− 5·88	+0·14	1	11, n f f	
2102	1 4 96	−19·82	−19·48	+0·34	2	10, s f	
3227	8 5 96	−39·09	−39·55	−0·46	1	10, s f f	
	12 5 96	−38·95	−39·05	−0·10	1		Not B, twilight and haze.
3615	8 5 96	+37·57	+37·69	+0·12	1	11, p	
	12 5 96	+37·67	+37·71	+0·04	1		
4473	5 9 96	+44·53	+44·76	+0·23	2	9·5, p	Very soft condens.
4499	1 9 96	−15·95	−16·06	−0·11	2	9, s f	Almost like a cluster.
	5 9 96	−16·07	−15·97	+0·10	2		Nice object.
4510	10 9 96	+14·98	+15·08	+0·10	2	11·5, p	
	11 9 96	+15·01	+15·18	+0·17	2	12, p	
4572	19 9 95	+53·97	+54·51	+0·54	2	9·0 p	
	21 9 95	+54·15	+54·69	+0·54	2		
4586	22 9 95	+ 7·34	+ 7·41	+0·07	2	9, s p p	
	16 10 95	+ 7·36	+ 7·32	−0·04	2		
4608	22 9 95	−18·62	−18·55	+0·07	2	9·5, f	
	17 10 95	−19·34	−18·70	+0·64	2		L, v l b M, l E p f (* is s p one of 2).
4625	20 9 95	+46·53	+46·73	+0·20	1	8·5, s p	
	21 9 95	+46·72	+47·04	+0·32	1		

G.C.	Date.	T.	M.	M−T.	Cond.	Star.	Notes.
		s	s	s			
4678	19 9 95	−11·65	−11·08	+0·57	2	9·5, n f	
	21 9 95	−11·48	−10·79	+0·69	2		Good object to measure.
4734	20 9 95	+12·10	+12 29	+0·19	1	10, n n p	
	22 9 95	+11·68	+12·22	+0·54	1	9·5, n n p	
4760	1 9 96	−13·37	−12·91	+0·46	2	11, s f	B, p L.
	5 9 96	−13 42	−13·07	+0·35	2		
4808	22 10 95	− 6·13	− 6·10	+0·03	1	10, n f	p F, p L, m b M.
4815	10 9 96	−33·78	−34·14	−0·36	1	11, n f	
	11 9 96	−34·01	−34·13	−0·12	1		
4821	16 10 95	− 3·37	− 2·97	+0·40	1	10, s s f	s m b M.
	17 10 95	− 3·31	− 3·22	+0·09	1		
4824	17 10 95	+18 32	+18·57	+0·25	2	Same *	
4879	17 10 95	−10·37	−10·29	+0 08	2	10, f	
	18 10 95	−10·34	−10·39	−0·05	2		
4880	17 10 95	−19·36	−18·81	+0·45	2	9, f	Rather F for B wires.
	18 10 95	−19·76	−18·74	+1·02	2		v l condens., diffused.
4921	22 10 95	+25·44	+25·81	+0·37	1	8·5, n p	p B, p L, m b M.
	14 11 95	+25·15	+25·77	+0·62	1		p F.
4939	1 11 96	−26·70	−26·75	−0·05	2	8, n f f	Brighter towards a point nearer s f edge.
	3 11 96	−26 67	−26 46	+0·19	2	7·5, f	
4966	22 10 95	+ 8·63	+ 8·75	+0·12	1	9·5, p	
	11 12 95	+ 8·63	+ 8·44	−0·19	1		
5020	1 11 96	+39·70	+40·16	+0·46	2	10, s p	[n p]
	4 11 96	+39·62	+39·50	−0·12	2	11, n p	* almost in line with 2 neb.
5022	4 11 96	+60·23	+60·32	+0·09	2	Same *	
5029	5 11 96	+17·40	+17·41	+0·01	1	8·8, p	

The mean of the column M−T ought now to represent my personal error, and is

$$+0^{s}\cdot206$$

or $+0^{s}\cdot202$ of each value of M−T is multiplied by $\cos\hat{c}$.

Taking the two classes of objects separately we get:

For much condensed nebulæ	+0·118
For little condensed nebulæ	+0·277

The result of this investigation is, therefore, that I am, like Schönfeld, inclined to note the transits of nebulous objects too early, and that my error, like his, is much smaller for a nebula

with a good nucleus than for more diffused objects—which is only natural. Though I am not conscious of any peculiarity in my mode of observing, I am inclined to think that this error may arise from the fact that the nebula on approaching the illuminated wire becomes somewhat fainter, which may induce an observer to anticipate the actual moment of transit.

It is of interest to compare my results with those of a recent attempt by Dr. Mönnichmeyer, of Bonn, to deduce the corrections necessary to reduce various observations of nebulæ to a homogeneous system.* Dr. Mönnichmeyer, who has observed about two hundred nebulæ with an annular micrometer, first determined his own personal error in star transits, as far as it depends on magnitude, by observing stars of various magnitudes in the *Pleiades*, and comparing the results with Dr. Elkin's heliometer measures. This equation depending on magnitude he calls ΔH^s_α. Supposing now that his nebular personal error is approximately represented by his stellar error thus found, then, if Schultz's and Vogel's results are practically free from systematic errors, the differences between their Right Ascensions and those of Dr. Mönnichmeyer ought to be equal to this ΔH_α. And even if the measures of Schultz and Vogel are affected by sensible errors, the said differences might still be represented by ΔH_α, if M's personal equation is a product of various sources of error, by some of which the observations of Schultz and Vogel are equally affected. In this case the ΔH_α would represent the reductions of M's observations to the "filar micrometric system of Schultz and Vogel"; and if all measures can be reduced to a common system, it will of course be of no consequence for future investigations of proper motion whether ΔH_α is to be considered as relative or absolute error. Assigning a certain stellar magnitude to every observed nebula, Dr. Mönnichmeyer divides the objects into classes according to the difference of magnitude between nebula and comparison star. From the difference "other observer minus Mönnichmeyer" ΔH_α is subtracted, and the difference is called $\Delta\alpha'$. This should be zero, if ΔH_α represents the reduction to a common system, and so it is in the cases of Schultz and Vogel. If not equal to zero, $\Delta\alpha'$ represents the personal error of the other observer. In this manner the following constant personal errors were found :—

	s		s
Schönfeld I.	+0·24	Engelhardt	−0·21
Schönfeld II.	+0·09	Kempf	+0·05
Dreyer	+0·14		

These observers seem, therefore, not to be sensibly influenced by the difference of magnitude between nebula and star. But Schmidt's Right Ascensions appear to be affected by approximately the same systematic errors as those of Dr. Mönnichmeyer

* *Veröffentlichungen der K. Sternwarte zu Bonn*, No. 1, "Beobachtungen von Nebelflecken am sechszölligen Refractor von Dr. C. Mönnichmeyer."

are, as Schmidt's error is $=\frac{1}{3}\Delta H_\alpha$. Similarly Rümker's error is $=\frac{2}{4}\Delta H_\alpha$, and Ginzel's $=2\Delta H_\alpha$. As a final test of all these results, they were applied to the single differences betwen M and the various observers, and the mean $\Delta\alpha$ comes out as $0^s{\cdot}00$ or $0^s{\cdot}01$ in all cases except that of Ginzel, where it is $+0^s{\cdot}04$, so that his personal error as found by this investigation is a little too small, while the reduction to the Vogel-Schultz system in the other cases seems a perfect one. Though these results, considered as absolute personal errors, perhaps in some cases (*e.g.* in Schönfield's, where they seem rather smaller than we should have expected) may be a little modified by future investigations, the differences between them agree well with those found by direct comparison.

My own relation to Schultz may be made out in several ways, either by direct comparison or through the medium of other observers. I have already in the paper in the *Trans. R.I. Acad.* given the result of the direct comparison of twenty-six objects observed by Schultz and myself, viz. Schultz—Dreyer $= +0^s{\cdot}07$; but this is not entitled to any great weight, as twelve of the objects are well condensed and give $0^s{\cdot}00$, while only fourteen are slightly condensed and give $+0^s{\cdot}13$. The results of indirect comparison through four observers, with whom both Schultz and I have many objects in common, are probably much more reliable, and they agree closely *inter se*.

	s
Through Schönfeld I.	+0·23
„ „ II.	+0·19
„ Engelhardt	+0·25
„ Mönnichmeyer	+0·18
Mean	+0·21

As this result for the difference Schultz-Dreyer is in perfect accordance with my absolute personal error as found from my recent observations, it may be assumed as well-established facts that Schultz's observations are practically free from systematic errors, and that my own absolute error in observing transits of nebulæ is very close to $+0^s{\cdot}2$. It is true that the value found by Dr. Mönnichmeyer for the latter quantity, $+0^s{\cdot}14$, is somewhat smaller; but as it was only derived from nineteen objects, nearly all (by ill luck) having a strong central condensation, this smaller value is also in very good agreement with the absolute error ($+0^s{\cdot}12$) which I found for nebulæ with a well-marked nucleus.

We may therefore look forward to the ultimate determination of proper motions of nebulæ with more confidence than hitherto, as we are getting the systematic errors well under control. The fact must, however, not be lost sight of, that in applying corrections for personal error to the observed places

proper attention must be paid to the degree of condensation of the objects. But there is an obvious way of avoiding systematic errors altogether (except such as are well within the limit of accuracy attainable in such observations) by giving up observations of transits and measuring both $\Delta\alpha$ and $\Delta\delta$ by the micrometer screw. As this can only be done by selecting comparison stars among those visible in the same field with each nebula, and such stars in many cases cannot be observed on the meridian, observers will have to sacrifice the pleasure of putting together a list of Right Ascensions and Declinations of the nebulæ they have measured. But this small sacrifice will be well compensated by the avoidance of the difficulty of assigning to each object the proper amount of systematic error.

Armagh Observatory:
1896 *December.*

On the Inequality in the Apparent Diurnal Movement of Stars due to refraction, and a method of allowing for it in Astronomical Photography. By Prof. Arthur A. Rambaut, M.A., D.Sc.

It is obvious that the varying effect of refraction in the Earth's atmosphere to which the light of a star is subjected as its hour-angle changes will cause inequalities in its apparent diurnal movement, and that no uniform equatorial movement will enable a telescope to follow a star for long periods of time when the highest accuracy is aimed at.

The irregularities in the apparent motion of stars due to local and temporary changes in the refraction are well known to astronomers who have had experience in stellar photography, but I doubt whether the perfectly regular and systematic change as the star alters its position in the sky has received the attention on the part of astronomers which its importance seems to demand.

Speaking generally, the hour-angle of a star is diminished by the refraction when approaching its upper culmination, but to a continually decreasing extent, and consequently the motion of the star at this part of its course appears slower than it actually is. At first sight it might perhaps appear that the effect at the western side of the meridian would be of an exactly opposite kind, and that the stars at this part of their diurnal track would appear to move more rapidly than they actually do. But a moment's reflection will show that this is not the case, for the refraction throwing the apparent to the following side of the true image in this case, and the displacement continually increasing as the star sinks in the west, the apparent will fall ever more and more behind the true position.

Now this inequality in the apparent movement occasions a great part of the difficulty in making a telescope follow accurately for long periods of time, and necessitates most of the watching and guiding by hand which renders a long exposure so laborious and fatiguing. The equatorial movement of the instrument being a uniform one, it is impossible to rate an equatorial clock so as to follow a star with equal accuracy at all parts of its course. The changes in the refraction are, indeed, from one point of view so slow that in most cases the clock can be rated to follow a particular star with sensible accuracy for reasonable intervals of time; but no adjustment will suit all stars equally well, and to obtain the best results the rate of the clock ought in each case to be adjusted for the particular star under consideration, and if the exposure is prolonged the rate ought to be suitably altered from time to time.

As an example, I may state here, in order to show that the differences to which I refer are not negligible quantities, that if a clock were rated by the motion of a star at the zenith in these latitudes, it would gain more than one-thirtieth of a second of time each minute on a star crossing the meridian at declination $77\frac{1}{2}°$, which would cause the star to fall behind the cross wires at the rate of one-tenth of a second of *arc* per minute; a rate of displacement which would very soon make itself sensible in any telescope of moderate dimensions. At a distance from the meridian the differences would be greater; and if the exposure were continued for, say, four hours, it would require frequent hand correction, amounting in the aggregate to more than 24 seconds, to counteract its effect.

It will thus be seen that the varying effect of refraction at different parts of the sky upon the motion of a star is quite noticeable, and that if this disturbance could be removed the art of steering a photo-telescope so as to point continuously at a given star, which, under the most favourable circumstances, is no easy task, might be rendered much less exacting and severe.

My attention has been specially directed to this question by the fact that in the class of work to which I have devoted our telescope at the Observatory of Trinity College, Dublin, viz., the measurement of stellar parallax, it is often necessary to take photographs of star groups at considerable hour-angles when the effect of refraction is most noticeable. If the observer's object is merely to obtain pictures of star groups, the work can be so arranged that each object is photographed when it arrives at or near the meridian. Thus almost all Dr. Roberts' photographs were taken at small hour-angles. The photographs for the international photographic survey of the heavens are also taken close to the meridian, where the variation in the angular movement of stars is least felt.

It is different, however, when it is intended to utilise the plates for the detection of stellar parallax. In connection with this research, it is desirable that a large proportion of the photographs

of each object should be taken when the star is near the apses of its parallactic ellipse, and this condition often necessitates photographing a star at hour-angles of six hours or more.

I have thus been led to examine minutely the effect of refraction on the movement of a star; and since a method which enables good photographs to be taken comparatively easily at any altitude, provided the atmosphere is steady enough for good seeing, cannot fail to be useful, perhaps a description of the means I have been led to adopt for this purpose may prove of interest to many who are engaged in this or other branches of stellar photography.

Let us examine what the effect of refraction is. If we denote the apparent western hour-angle of a star by h, the effect of refraction in hour-angle by Δh, the right ascension by α, and the sidereal time by θ, we have

$$h = \theta - \alpha + \Delta h,$$
$$\frac{dh}{d\theta} = 1 + \frac{d\Delta h}{d\theta}.$$

Hence the expression $\frac{d\Delta h}{d\theta}$ measures the rate at which the apparent movement of a star gains on its mean movement or on sidereal time.

To calculate this quantity we have the equation:

$$\left.\begin{aligned} &\sin\eta \cot \Delta h = \cot \Delta\zeta \cos\delta - \sin\delta\cos\eta \\ \text{Also}\quad &\sin(\delta+\Delta\delta) = \sin\delta\cos\Delta\zeta + \cos\delta\sin\Delta\zeta\cos\eta \end{aligned}\right\} \quad \ldots\ldots (a)$$

in which δ denotes the declination, ζ the zenith distance, and η the parallactic angle, of the star, and $\Delta\zeta$, Δh, and $\Delta\delta$ are the effects of refraction in ζ, h, and δ respectively. For our present purpose we may put $\Delta\zeta = \beta \tan\zeta$, β being a function of ζ and so small that we may neglect its square and higher powers.

Hence

$$\Delta h = \beta \tan\zeta \sin\eta \sec\delta = \beta.\psi, \text{ say.}$$

Differentiating, we find

$$\frac{d\Delta h}{d\theta} = \beta\frac{d\psi}{d\theta} + \psi\frac{d\beta}{d\theta}.$$

Except in the immediate vicinity of the horizon, the second term in this may be neglected,* and we get, therefore,

$$\frac{dh}{d\theta} = 1 + \beta\frac{d\psi}{d\theta}.$$

* See a paper in the *Astronomische Nachrichten*, No. 3.125, on "The Corrections for Refraction to Measures of Stellar Photographs."

Also by the ordinary formulæ of transformation, if ϕ denotes the latitude of the observatory, we have

$$\psi = -\frac{\cos\phi}{\cos\delta}\cdot\frac{\sin h}{\sin\delta\sin\phi+\cos\delta\cos\phi\cos h};$$

and therefore

$$\frac{dh}{d\theta} = 1-\beta\frac{\cos\phi}{\cos\delta}\cdot\frac{\cos\delta\cos\phi+\sin\delta\sin\phi\cos h}{\{\sin\delta\sin\phi+\cos\delta\cos\phi\cos h\}^2}.$$

Assuming m, n, μ, ν such that

$$\tan m = \cot\phi\cos h \qquad \cot\mu = \tan\phi\cos h$$
$$\cot n = \sin m\tan h \qquad \cot\nu = \cos\mu\tan h$$

this may be written in the form

$$\frac{dh}{d\theta} = 1-\beta\frac{\cos\phi}{\cos\delta}\cdot\frac{\sin\nu\sin(\mu+\delta)}{\sin^2 n\sin^2(m+\delta)} \quad . \quad . \quad . \quad . \quad . \quad (\beta)$$

If it were required that the telescope should follow the star with absolute precision, it would be necessary to construct a clockwork system which would drive the instrument at a rate varying continually with the hour-angle according to the law expressed by this formula (β). In practice, however, it is sufficient to alter the rate at intervals, the length of which will depend upon the rapidity of the changes in the refraction, provided always that the error thus introduced does not exceed a certain definite limit.

From the formula (β) I have computed the values of $\frac{dh}{d\theta}-1$ for every tenth degree in declination, and for every even hour in hour-angle, and from the quantities thus obtained I have drawn the series of curves in fig. 1, in which the abscissæ denote the gaining or losing rate of the star as compared with sidereal time, expressed in the usual way as so many seconds a day.

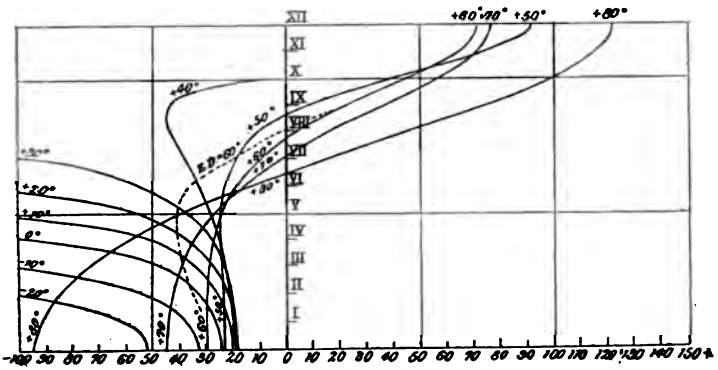


FIG. 1.

Now an examination of these curves shows that, even when the change in the rate of movement is most rapid, a uniform rate, *if suitably chosen*, will not in ten minutes introduce an error amounting to the one-twentieth of a second, which is about the limit within which the accidental errors of a good equatorial clock can be kept. This, then, would appear to be the limit of time for which, in cases of extremely rapid changes in the stars' movements, a uniform rate may be used. In most cases a longer interval is allowable.

If the exposure is prolonged beyond the period for which a uniform rate is permissible, it will be necessary to alter the rate from time to time in such a way that the algebraic sum of the errors thus introduced, alternately in excess and defect, shall be always less than the assumed limit of accuracy.

This is particularly easy to manage with a clock controlled by the action of a pendulum. By employing a series of weights the effect of which on the period of oscillation of the pendulum has been ascertained, and by suitably altering the weights upon the shelf of the pendulum from time to time as the diagram shows to be necessary, the movement of the clock, and consequently that of the telescope, can be made to agree with the apparent rate of movement of the star to any degree of precision required.

The length of exposure for which a uniform rate is permissible is determined in the following way from the curve drawn, as in fig. 1, for the declination of the star :—

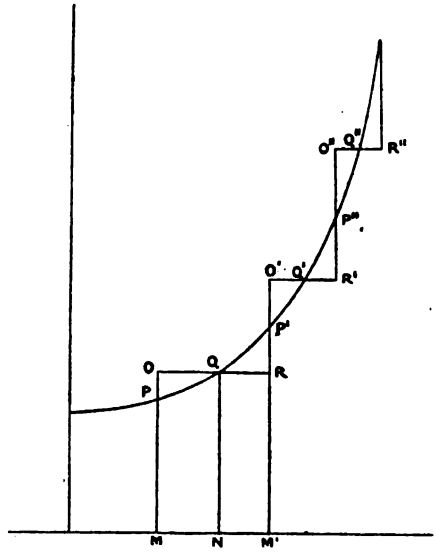


Fig. 2.

If r is the variable rate at which the star gains on the mean sidereal movement as given by formula (β), then the total gain in the interval $t'-t$ is $\int_t^{t'} r\,dt$.

If for the same interval of time we take a uniform rate r', the amount which the motion of the telescope gains on mean sidereal movement is $r'(t'-t)$, and the amount by which the telescope gains upon the star is represented by the difference between these two expressions. But the first is in fig. 2 represented by the area PP'M'M under the curve, while the second is the parallelogram ORM'M. Hence the displacement of the telescope with regard to the star at the end of the exposure is measured by the difference of the two areas OPQ and QRP', and by taking a uniform rate represented by QN, corresponding to about the middle of the exposure, it can be used for the whole interval MM' provided that neither area OPQ nor QRP' exceeds the assumed limit of accuracy.

On the scale I have used, viz., 1^{mm} in the abscissæ to represent a rate of 1^s per day and 10^{mm} in the ordinates to represent an hour, this area, corresponding to a gain or loss of one-twentieth of a second, is 12 square millimetres, which at once enables us to judge for what length of exposure we may venture to use a uniform rate.

By drawing a zigzag line such that the approximately triangular areas contained between it and the curve shall never

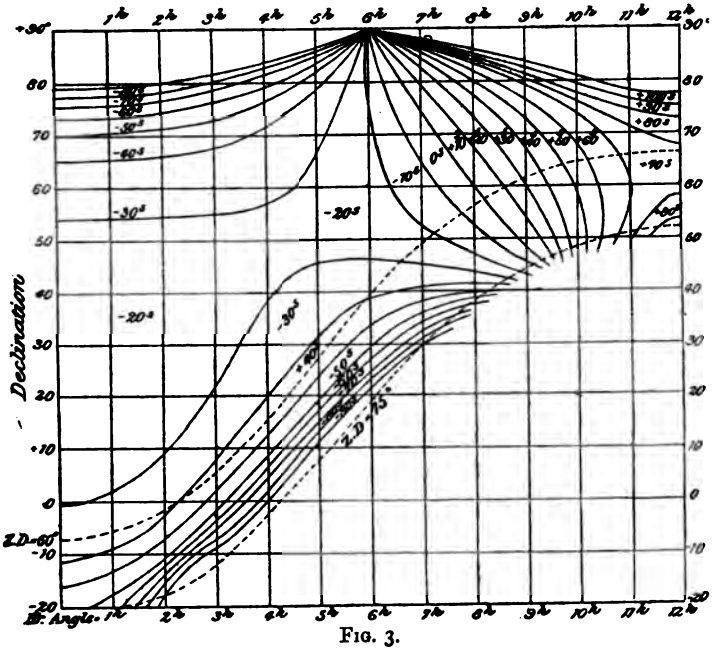


FIG. 3.

exceed 12 square millimetres, we get a series of uniform rates which will keep the pointing of the telescope constantly within one-twentieth of a second of the star.

When only short exposures of 5 or 10 minutes are necessary, as is generally the case with plates intended for accurate measurement, in which it is advisable to keep the star discs as small as possible, a still simpler method is available. By plotting down on squared paper the points on the sky for which the appropriate rates are -105^s, -95^s, . . . -5^s, $+5^s$, . . . $+95^s$, $+100^s$ a day, the abscissæ representing hour-angles and the ordinates representing declinations, we get a series of curves the spaces between which represent the regions of the sky for which the appropriate rates are -100^s, -90^s, . . . 0^s, . . . $+90^s$, $+100^s$ a day, and thus by a simple reference to this diagram, fig. 3, it is possible to read off the suitable clock-rate with sufficient accuracy.

This method I have found most convenient in practice for short exposures. I can turn the telescope with the greatest confidence from a star at its upper culmination, to follow which a star must lose at the rate of from 18 to 100 seconds or more a day, according to the declination, to another at its lower culmination apparently gaining at the rate of 70 or 80 seconds a day, and I find the telescope will follow both with equal accuracy.

The following table contains the rates suitable to each degree of declination, interpolated from the computed values referred to above, for the latitude of Dublin ($53° 23' 13''$), and will serve to show through what a wide range the apparent angular velocity of a star varies. In this table + denotes a gaining, and — a losing, rate as compared with mean sidereal time.

TABLE.

Hour Angle.

Decl.	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	12^h
°	s	s	s	s	s	s	s	s	s	s	s	s	s
−20	−52·0	−61·2	−104·1	...	...	...	...	...	...	...	...	...	...
19	−49·4	−58·0	− 97·4	...	...	...	...	...	...	...	...	...	...
18	−46·9	−54·8	− 91·1	...	...	...	...	...	...	...	...	...	...
17	−44·6	−52·0	− 85·3	...	...	...	...	...	...	...	...	...	...
16	−42·5	−49·3	− 79·8	...	...	...	...	...	...	...	...	...	...
15	−40·5	−46·8	− 74·6	...	...	...	...	...	...	...	...	...	...
14	−38·6	−44·6	− 69·8	...	...	...	...	...	...	...	...	...	...
13	−36·9	−42·4	− 65·4	...	...	...	...	...	...	...	...	...	...
12	−35·4	−40·4	− 61·2	...	...	...	...	...	...	...	...	...	...
11	−33·9	−38·5	− 57 5	...	...	...	...	...	...	...	...	...	...
10	−32·7	−36·8	− 54·0	−110·1	...	...	...	...	...	...	...	...	...
9	−31·5	−35·3	− 50·9	−100·7	...	...	...	...	...	...	...	...	...
8	−30·4	−34·0	− 48·1	− 92·2	...	...	...	...	...	...	...	...	...
7	−29·4	−32·8	− 45·5	− 84·3	...	...	...	...	...	...	...	...	...
6	−28·6	−31·6	− 42·0	− 77·2	...	...	...	...	...	...	...	...	...
5	−27·8	−30·5	− 40·8	− 70·9	...	...	...	...	...	...	...	...	...
4	−27 0	−29·5	− 38·7	− 65·2	...	...	...	...	...	...	...	...	...
3	−26·2	−28·5	− 36·8	− 60·1	...	...	...	...	...	...	...	...	...
2	−25·6	−27·6	− 35 2	− 55·6	...	...	..	...	...	...	...	...	...

Decl.	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	12^h
°	s	s	s	s	s	s	s	s	s	s	s	s	s
−1	−24·9	−26·8	− 33·7	− 51·5	...	...	...	...	...	...	...	...	...
0	−24·3	−26·1	− 32·3	− 48·1	−94·0	...	...	...	...	...	...	...	...
+1	−23·8	−25·5	− 31·3	− 46·1	−88·0	...	...	...	...	...	...	...	...
2	−23·3	−25·0	− 30·4	− 44·1	−82·5	...	...	...	...	...	...	...	...
3	−22·9	−24·4	− 29·6	− 42·3	−77·3	...	...	...	...	...	...	...	...
4	−22·4	−23·9	− 28·8	− 40·7	−72·5	...	...	...	...	...	...	...	...
5	−22·0	−23·4	− 28·0	− 39·1	−68·2	...	...	...	...	...	...	...	...
6	−21·6	−23·0	− 27·3	− 37·6	−64·1	...	...	...	...	...	...	...	...
7	−21·3	−22·5	− 26·6	− 36·3	−60·4	...	...	...	...	...	...	...	...
8	−20·9	−22·1	− 26·0	− 35·1	−57·0	...	...	...	...	...	...	...	...
9	−20·6	−21·8	− 25·4	− 32·9	−53·9	...	...	...	...	...	...	...	...
10	−20·3	−21·4	− 24·9	− 32·8	−51·1	−104·2	...	...	...	...	...	...	...
11	−20·0	−21·1	− 24·5	− 31·9	−48·7	− 97·2	...	...	...	...	...	...	...
12	−19·8	−20·8	− 24·0	− 31·0	−46·8	− 90·8	...	...	...	...	...	...	...
13	−19·6	−20·5	− 23·6	− 30·2	−45·0	− 84·8	...	...	...	...	...	...	...
14	−19·4	−20·3	− 23·2	− 29·4	−43·2	− 79·4	...	...	...	...	...	...	...
15	−19·2	−20·1	− 22·9	− 28·7	−41·6	− 74·3	...	...	...	...	...	...	...
16	−19·1	−19·9	− 22·6	− 28·1	−40·0	− 69·6	...	...	...	...	...	...	...
17	−18·9	−19·7	− 22·3	− 27·5	−38·6	− 65·4	...	...	...	...	...	...	...
18	−18·8	−19·5	− 22·0	− 26·9	−37·2	− 61·6	...	...	...	...	...	...	...
19	−18·7	−19·3	− 21·8	− 26·4	−36·0	− 58·0	...	...	...	...	...	...	...

Decl.	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	12^h
°	s	s	s	s	s	s	s	s	s	s	s	s	s
20	−18·6	−19·2	− 21·7	− 25·9	−34·9	− 54·7	−110·0	...	...	...	...	...	...
21	−18·5	−19·1	− 21·5	− 25·5	−34·0	− 52·2	−102·0	...	...	...	...	...	...
22	−18·5	−19·0	− 21·3	− 25·1	−33·1	− 49·9	− 94·5	...	...	...	...	...	...
23	−18·4	−18·9	− 21·1	− 24·8	−32·2	− 47·8	− 87·6	...	...	...	...	...	...
24	−18·4	−18·8	− 21·0	− 24·4	−31·4	− 45·8	− 81·2	...	...	...	...	...	...
25	−18·3	−18·8	− 20·9	− 24·1	−30·7	− 43·9	− 75·3	...	...	...	...	...	...
26	−18·3	−18·8	− 20·8	− 23·8	−30·0	− 42·1	− 69·9	...	...	...	...	...	...
27	−18·3	−18·7	− 20·7	− 23·6	−29·4	− 40·5	− 65·1	...	...	...	...	...	...
28	−18·3	−18·8	− 20·6	− 23·3	−28·8	− 38·9	− 60·7	...	...	...	...	...	...
29	−18·4	−18·8	− 20·4	− 23·1	−28·2	− 37·5	− 56·6	...	...	...	...	...	...
30	−18·4	−18·8	− 20·2	− 22·9	−27·7	− 36·2	− 52·9	−92·2	...	...	...	...	...
31	−18·4	−18·8	− 20·2	− 22·7	−27·3	− 35·1	− 49·9	−84·5	...	...	...	...	...
32	−18·5	−18·9	− 20·3	− 22·6	−26·9	− 34·0	− 47·4	−77·4	...	...	...	. .	...
33	−18·7	−18·9	− 20·3	− 22·4	−26·5	− 33·1	− 45·2	−70·8	...	...	...	...	...
34	−18·8	−19·0	− 20·3	− 22·3	−26·1	− 32·2	− 43·0	−64·8	...	...	...	...	...
35	−18·9	−19·2	− 20·3	− 22·2	−25·8	− 31·3	− 40·8	−59·2	...	...	...	...	...
36	−19·0	−19·3	− 20·4	− 22·2	−25·5	− 30·5	− 38·8	−54·1	...	...	...	...	...
37	−19·1	−19·4	− 20·4	− 22·2	−25·2	− 29·7	− 37·0	−49·4	...	...	...	...	...
38	−19·2	−19·6	− 20·4	− 22·2	−24·9	− 29·0	− 35·3	−45·3	...	...	...	...	...
39	−19·4	−19·7	− 20·5	− 22·2	−24·7	− 28·4	− 33·8	−41·5	...	..	...	...	...
40	−19·6	−19·9	− 20·7	− 22·2	−24·5	− 27·8	− 32·3	−38·1	−43·9	−42·8	...	...	...

Decl.	0h	1h	2h	3h	4h	5h	6h	7h	8h	9h	10h	11h	12h
°	s	s	s	s	s	s	s	s	s	s	s	s	s
41	−19·8	−20·1	− 20·8	− 22·2	−24·3	— 27·3	− 31·1	−35·6	−39·1	−34·8	...	...	...
42	−20·1	−20·3	− 21 0	− 22·3	−24·1	− 26·9	− 29·9	−33·2	−34·5	−27·4	...	...	...
43	−20·5	−20·6	− 21·2	− 22·4	−24·0	− 26·4	− 28·9	−30·9	−30·4	−20·8	...	...	...
44	−20·8	−20·9	− 21·5	− 22·6	−23 9	-- 26·0	− 27·9	−28·8	−26·5	−14·8	...	...	...
45	−21·1	−21·2	− 21·7	− 22 7	−23·8	− 25·6	− 26·9	−26·8	−23·0	− 9·5	...	...	...
46	−21·4	-- 21·5	− 22 0	− 22·8	−23·8	− 25·3	− 26 0	−25 1	−19·8	− 4·7	...	...	...
47	−21·7	−21·8	− 22·2	− 23·0	−23 8	− 24·9	− 25·1	−23·4	−16·9	− 0·4	...	...	...
48	−22·1	−22·1	− 22·5	− 23·2	−23 9	− 24 6	− 24·3	−21·8	−14·1	+ 3·4	...	..	...
49	−22·4	−22·5	− 22·8	− 23·4	−24 0	− 24·3	− 23·6	−20 3	−11·9	+ 6 7	...	...	...
50	-·22·8	−22 9	-· 23·2	- 23·6	−24 1	− 24·1	− 22·9	−18·9	− 9 4	+ 9·6	...	...	...
51	−23·3	−23·3	− 23·7	− 23·9	−24 2	− 23·9	− 22·3	−17·5	− 7·4	+11 8	+41·3	+ 73·9	+ 89·0
52	−23 8	−23 8	− 24·1	− 24·3	−24·4	− 23·7	− 21 7	−16·3	− 5·6	+13·6	+42·2	+ 72·6	+ 86 5
53	−24·3	−24·3	− 24·6	− 24·7	−24·5	− 23·5	− 21·1	−15·2	− 3·9	+15·3	+42·9	+ 71·4	+ 84·1
54	−24·9	−25·0	− 25 0	− 25·0	−24·7	− 23·4	− 20·5	−14·2	− 2 4	+16·8	+43·4	+ 70·2	+ 81·8
55	−25·6	−25·6	− 25·5	− 25·4	- 25·0	− 23·3	− 20·0	−13·2	− 1·1	+18 3	+43·8	+ 69 0	+ 79·7
56	−26·3	−26 2	− 26·1	− 25·8	−25·2	− 23 2	− 19·6	−12·3	+ 0·2	+19·5	+44·4	+ 67 8	+ 77·8
57	−27·0	−26·9	− 26·8	− 26·4	−25·4	− 23·1	− 19·2	−11·4	+ 1·5	+20·7	+44·7	+ 66·8	+ 76·0
58	−27·7	−27 6	− 27·5	− 27 0	−25·7	− 23·1	− 18·8	−10 6	+ 2 6	+21 8	+45·0	+ 65·9	+ 74·4
59	−28·5	−28·4	− 28·2	− 27·6	−26·1	− 23·2	− 18·4	− 9·8	+ 3·7	+22·8	+45·3	+ 65·1	+ 73·1
60	−29·4	−29·3	− 28·9	− 28·1	−26·4	− 23·3	− 18 0	− 9 0	+ 4 8	+23·8	+45·7	+ 64·5	+ 72 0
61	−30·4	−30·3	− 29·8	− 28·8	−26·7	− 23·4	− 17·6	− 8·2	+ 5·9	+24·6	+46·1	+ 64·0	+ 71·0

Decl.	0^h	1^h	2^h	3^h	4^h	5^h	6^h	7^h	8^h	9^h	10^h	11^h	12^h
°	s	s	s	s	s	s	s	s	s	s	s	s	s
62	−31·5	−31·3	− 30·9	− 29·7	−27·4	− 23·5	− 17·2	− 7·5	+ 6·8	+25·3	+46·5	+ 63·7	+ 70·4
63	−32·8	−32·6	− 32·0	− 30·6	−28·0	− 23·7	− 16·9	− 6·7	+ 7·9	+26·3	+47·1	+ 63·7	+ 70·1
64	−34·1	−33·9	− 33·1	− 31·5	−28 7	− 23·9	− 16·5	− 5·9	+ 9·0	+27·3	+47 9	+ 64·0	+ 70·1
65	−35·6	−35·4	− 34·3	− 32·5	−29·4	− 24·2	− 16·2	− 5·2	+10·1	+28·4	+48·9	+ 64·5	+ 70·5
66	−37·2	−36·9	− 35·7	− 33·6	−30·1	− 24·6	− 16·0	− 4·4	+11·3	+29·7	+50·2	+ 65·4	+ 71·0
67	−38·8	−38·5	− 37·2	− 34·8	−30·9	− 24·9	− 15 8	− 3·6	+12·6	+31·2	+51·6	+ 66·5	+ 72·0
68	−40·6	−40·2	− 38·8	− 36·1	−31·8	− 25·2	− 15·6	− 2·7	+14·0	+33·0	+53·2	+ 67·9	+ 73·3
69	−42·5	−42·0	− 40·5	− 37·5	−32·8	− 25·6	− 15·4	− 1·8	+15·5	+35·1	+55·0	+ 69·6	+ 74·9
70	−44·5	−44·0	− 42·3	− 39·0	−33·8	− 26·1	− 15·3	− 0·8	+17·3	+37·5	+57·0	+ 71·5	+ 76·9
71	−47·4	−46·9	− 44·9	− 41·2	−35·4	− 26·8	− 15·1	+ 0·2	+19·0	+39·9	+59·4	+ 73·9	+ 79·3
72	−50·9	−50·2	− 47·8	− 43·5	−37·1	− 27·6	− 14·9	+ 1·4	+21·0	+42·3	+62·1	+ 76·8	+ 82·2
73	−54·5	−53·8	− 51·2	− 46·3	−38 9	− 28·6	− 14·7	+ 2·7	+23·1	+45·0	+65·2	+ 80·0	+ 85·5
74	−58·7	−57·8	− 54·8	− 49·2	−41·1	− 29·7	− 14·5	+ 4·0	+25·5	+48·1	+68·7	+ 83·7	+ 89·2
75	−63·3	−62·2	− 58·8	− 52·6	−43·5	− 30·9	− 14·4	+ 5·4	+28·1	+51·5	+72·7	+ 87 8	+ 93·4
76	−68·4	−67·1	− 63·2	− 56·2	−46·1	− 32·1	− 14·3	+ 7·0	+30·9	+55·2	+77·1	+ 92·3	+ 98·1
77	−74·0	−72·5	− 68·1	− 60·2	−48·9	− 33·5	− 14·2	+ 8·6	+33·9	+59·4	+81·8	+ 97·5	+103·3
78	−80·2	−78·5	− 73·4	− 64·6	−52·0	− 35·1	− 14·1	+10 3	+37·2	+64·0	+87·0	+103·1	+109·0
79	−86·8	−84·9	− 79·3	− 69·4	−55·3	− 36·8	− 14·0	+12·3	+40·8	+68·8	+92·8	+109·2	+115·2
80	−94·0	−91·9	− 85·5	− 74·6	−59·0	− 38·7	− 13·9	+14·5	+44·8	+74 2	+99·1	+115·9	+121·9

I may add that it is often a convenience to know at what rate the refraction in declination varies during an exposure. This may be computed in a similar manner. From the second of equations (α) we find

$$\Delta\delta = \Delta\zeta \cos\eta = \beta \tan\zeta \cos\eta,$$

or

$$\Delta\delta = \beta \cdot \frac{\cos\delta \sin\phi - \sin\delta \cos\phi \cos h}{\sin\delta \sin\phi + \cos\delta \cos\phi \cos h}.$$

And since the apparent declination (δ') is equal to $\delta + \Delta\delta$, we have

$$\frac{d\delta'}{d\theta'} = \frac{d\Delta\delta}{d\theta} = \beta \cdot \frac{\sin\phi \cos\phi \sin h}{\{\sin\delta \sin\phi + \cos\delta \cos\phi \cos h\}^2} \quad \ldots\ldots (\gamma)$$

Hence we see that the apparent declination is always increasing on the west and always diminishing on the east of the meridian, as is otherwise obvious.

With the same substitution as before, we can write this expression in the form

$$\frac{d\delta'}{d\theta'} = \beta \frac{\cos\phi \cdot \cos\nu}{\sin^2 n \sin^2(m+\delta)} \quad \ldots\ldots\ldots (\delta)$$

which is very convenient for computation.

This also varies within limits, which, in comparison with the accuracy of which measurements of stellar photographs are susceptible, may be considered wide. It is of course zero on the meridian, while at a zenith distance of 60° (at which it is possible to get first-rate photographs for measurement) it may amount to as much as 0″·5 per minute.

Dunsink Observatory:
1896 *December* 1.

Observations of the Leonids on 1896 *November* 13 *and* 14.

By Prof. Arthur A. Rambaut, M.A., D.Sc.

Although our observations this year at Dublin of the meteors belonging to the *Leonid* stream fall far short of what we hoped for, and in point of accuracy and completeness leave a good deal still to be desired, yet in view of the unfavourable character of the weather, which prevented observations at so many other stations, the results we obtained may possibly be of value, and ought at least to be put on record.

Cloudy weather prevented observations on the night of November 12.

On the 13th my assistant, Mr. Charles Martin, commenced his watch at $12^h\ 55^m$ G.M.T. At that time it was very cloudy in the east, with a film of thin clouds all over the sky, which began to clear up shortly afterwards, and by $13^h\ 55^m$ had quite disappeared. The first meteor was recorded at $14^h\ 16^m$, and was followed by others as exhibited in the following table :—

TABLE I.

Observation of Meteors, 1896 November 13.

No.	Time first seen G.M.T. d	h	m	Point first seen at.	Mag.	Colour.	Notes.
1	13	14	16	π Leonis	2	Yellow	
2		14	25	o „	1	White	
3		14	45	Orion	1	Red	
4		14	47	λ Leonis	4	White	
5		14	49	κ „	4	„	
6		15	0	ζ „	3	„	
7		15	1	o „	4	„	
8		15	1	Orion—Leo	1	„	
9		15	2	ζ Leonis	1	Red	Seen for 14°. Drifted N.E.
10		15	13	Between γ and ζ Leonis	4	White	
11		15	16	„ ν and o Leonis	4	Yellow	
12		15	20	o Leonis	0	White	
13		15	31	ρ „	3	„	
14		15	40	ϵ Ursæ Majoris	−1	Yellow	Came from ϵ Ursæ Maj. and lasted till it reached Regulus.
15		15	44	θ Leonis	2	White	
16		15	47	κ „	3	„	
17		15	51	Between α Leonis and Jupiter	2	„	
18		15	56	20 Leonis	3	„	
19		16	0	θ „	4	Red	
20		16	3	λ „	2	Bright red	
21		16	25	γ „	−2	White	
22		16	40	η „	1	Yellow	

$12^h\ 55^m$, cloudy in E, clearing up, though very thin clouds all over the sky.
$13^h\ 55^m$, quite clear.
$16^h\ 55^m$, clouded up.
Moon set about $13^h\ 40^m$. Age at noon Nov. 13, $8^d\ 5^h$.

The last meteor was noticed at $16^h\ 40^m$ when the clouds

began to gather once more, and by $16^h\ 55^m$ the sky was so hopelessly overcast that the watch was discontinued.

The tracks of these meteors were plotted down by Mr. Martin at the time upon a map of the constellation *Leo* prepared before hand, and the results of his observations are reproduced in fig. 1.

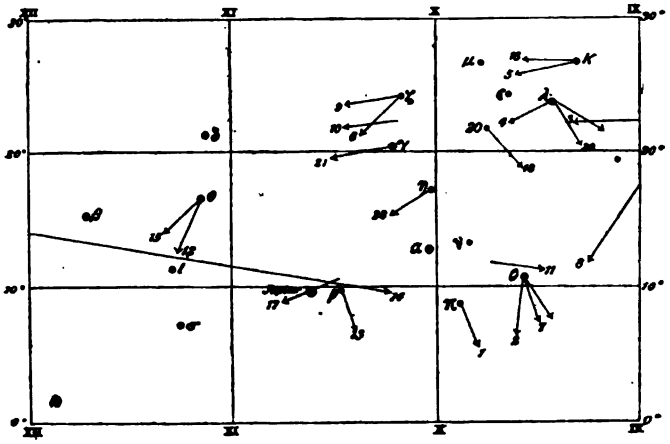


FIG. 1.—Meteor Tracks, 1896 November 13.

On the following day I attached a camera to the tube of our photographic equatorial in the hope of getting automatic records of some of the brighter meteor-trails. The lens was a rapid-rectilinear of $1\frac{1}{4}$ inch diameter (of which the full aperture was used), and about $8\frac{1}{2}$ inches equivalent focus. But although I employed Cadett & Neale's Lightning plates, $7\frac{1}{2}$ by 5 inches in size, which thus covered a region of about $50° \times 33°$ upon the sky, and although several of the meteors crossed the field of view covered by the lens, not a single one of them was bright enough to leave a trace upon the photograph.

It will at once be objected that the lens was too small, and, of course, I did not venture to hope that I should succeed in getting photographs of all the meteors which we saw; but I was disappointed to find that even the brighter ones, which appeared of about the first or second stellar magnitude, left no trace upon the plate.

My experiment, therefore, although the result is of a negative character, may possibly be of some use in affording a lower limit to the aperture of lens which can be used for this purpose with any prospect of success, and if the fainter meteors are looked for the lens will have to be of much larger dimensions.

Unfortunately this photographic experiment was not only unsuccessful, but was positively detrimental to the completeness of our watch on this night; for on account of the temporary and make-shift character of the apparatus I found it necessary to

call Mr. Martin in to help me in removing and replacing the cap.

His own observations, which he conducted as on the previous night, were in this way three times interrupted, but a continuous watch was maintained by him

	h	m	h	m
from	13	40	to 13	50 G.M.T.
„	14	19	„ 15	19 „
„	15	32	„ 16	31 „
„	16	53	„ 17	49 „

and his results are given in the following table :—

TABLE II.

Observation of Meteors, 1896 November 14.

No.	Time first seen (G.M.T.) d	h	m	Point first seen at.	Mag.	Colour.	Notes.
1	14	13	46	Between ζ and μ Leonis	1	White	Seen for 4°.
2		14	26	Between Jupiter and θ Leonis	2	„	
3		14	28	β Leonis	2	„	
4		14	32	Between μ and ϵ Leonis	1	Yellow	Seen for 5°.
5		14	42	o Leonis	4	White	
6		15	3	„	4	„	
7		15	3	θ „	4	„	
8		15	19	η „	6	Red	
9		15	40	δ „	4	White	
10		15	41	o „	3	Red	
11		15	41	θ „	2	White	Seen for 4°.
12		15	47	β „	4	„	
13		15	52	Between Jupiter and γ Leonis	2	„	
14		16	0	δ Leonis	5	Yellow	
15		16	3	o „	4	„	
16		16	6	γ „	2	„	
17		16	7	ϵ „	3	White	
18		16	10	Between Jupiter and θ Leonis	4	Yellow	
19		16	11	ζ Leonis	1–2	White	$1\frac{1}{2}$° long.
20		16	11	β „	2	„	
21		16	15	α Cancri (?)	4	„	
22		16	25	Jupiter	1	„	
23		17	1	ρ Leonis	2	„	
24		17	23	ν „	4	„	
25		17	47	20 „	4	„	

Moon set about $14^h\ 49^m$, age at noon November 14 $9^d\ 5^h$.

The tracks as plotted down by him are represented in fig. 2.

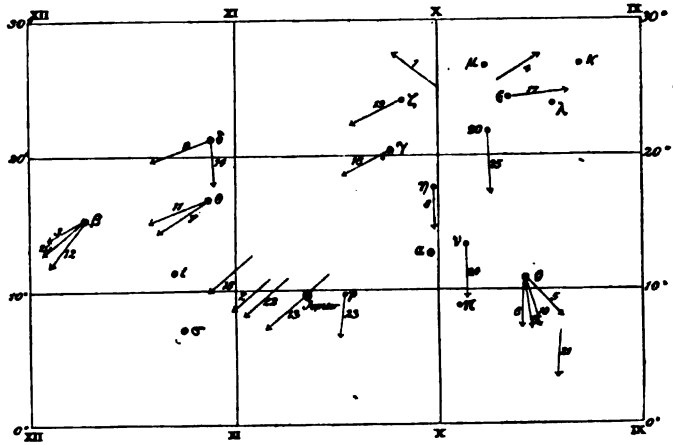


FIG. 2.—Meteor Tracks, 1896 November 14.

From the observations as given above we deduce the following table, giving the number of meteors seen in each successive period of ten minutes on the two mornings :—

TABLE III.

G.M.T.	No. of meteors seen on Nov. 13.	No. of meteors seen on Nov. 14.	G.M.T.	No. of meteors seen on Nov. 13.	No. of meteors seen on Nov. 14.
h m			h m		
13 40			50		
	0	1		2	1
50			16 0		
	0	[0]		2	3
14 0			10		
	0	[0]		0	4
10			20		
	1	[0]		1	1
20			30		
	1	1		0	[0]
30			40		
	0	1		1	[0]
40			50		
	2	1		...	0
50			17 0		
	0	0		...	1
15 0			10		
	3	2		...	0
10			20		
	2	1		...	1
20			30		
	1	[0]		...	0
30			40		
	1	0		...	1
40			50		
	2	4			

At first sight these observations seem to point to an increase in the number of meteors on both mornings in the interval between $14^h\ 30^m$ and $16^h\ 30^m$, which, if real, would be difficult to account for. I think, however, the apparent falling off in point of numbers towards the end of the first night's watch is possibly due to a gradual coming on of clouds, which is very likely to have preceded total obscuration, although Mr. Martin has not recorded it; and on the second night the light of the Moon, which set about $14^h\ 49^m$, and the small altitude of the constellation *Leo* at first may have conspired to render some of the meteors invisible. The increase in numbers at $14^h\ 40^m$ on November 13 and the falling off after $16^h\ 30^m$ on November 14 seem to be real, as the sky was clear at both times; and, I think, a more probable deduction from these observations, if, indeed, they are not too meagre to afford a basis for any such deduction, is that the densest part of the swarm which we passed through this year was encountered during the interval between our two watches—perhaps during the daylight hours of Saturday, 14th.

From the tracks as laid down by Mr. Martin, it would appear that the meteor trails of November 14 diverge much more nearly from a point than do those of the 13th; and although I would not rely too much on the absolute accuracy of any track—for I think the number of trails which are drawn as issuing from stars would show that the proximity of a bright star has biassed the observer's estimate of the position of the meteor's path—yet I am inclined to think that the greater divergence of the trails recorded on November 14 is not a mere chance result of errors of observation, but points to a real difference in the character of the paths on the two occasions.

In this connection I may remark, although, indeed, the fact might be used as an argument against this conclusion, that the three meteors which Mr. Martin notes as having lasted for several seconds, thus affording him a better opportunity of determining their paths, seemed to diverge almost exactly from the radiant point, as determined by Mr. Denning and given in the *Admiralty Manual* for 1886.

The following letters were read by Dr. Johnstone Stoney at the meeting of the Society on 1896 December 11 :—

Quinta Cuibem, Caminho do Til, Funchal, Madeira :
1896 November 27.

DEAR SIR,—In accordance with the request contained in the circular which you issued through the Royal Astronomical Society last July, I kept a watch upon the *Leonids* on the morning of the 14th inst., and immediately sent my observations to the journal of the British Astronomical Association, thinking that they would be in time for the November number of that paper, in which I expected you would probably see them. I find, however, that they were not in time for that number of the journal, and so I now venture to send them to yourself in case they may be of some use.

As I have not had experience in the charting of meteors, I did not attempt to map them, especially since you have pointed out in the November number of the *Observatory* that photography is the only satisfactory method for determining the radiant-point. I have no means of photographing the meteors here, and therefore confined myself to counting them and noting the times of their appearance, together with the directions of their flight (roughly), since it might perhaps assist in identifying a particular meteor. I kept an almost constant watch from G.M.T. $2^h\ 8^m$ until $6^h\ 10^m$, and the inclosed list contains all the undoubted *Leonids* which I saw, although of twenty-seven other meteors which I noted, several, perhaps four or five, were possible *Leonids*. On account of trees, I had to observe from an upper (open) window of a house, facing south-east, so that I may have missed some meteors which possibly appeared towards the north or north-west ; but I kept a good look-out up to the zenith, and from the north-east round by south to south-west.

Altogether I saw twenty-nine *Leonids*, as given in the list, and the curve given on the back of the latter shows their distribution in periods of half an hour each. There was a rapid increase in their numbers from 4 o'clock until 5.30.

The Earth does not appear to have met with the beginning of the meteor-stream during the period of my watching, but perhaps observers further west have been better rewarded.

Trusting that my notes may be of some use to you,

I am, yours very sincerely,

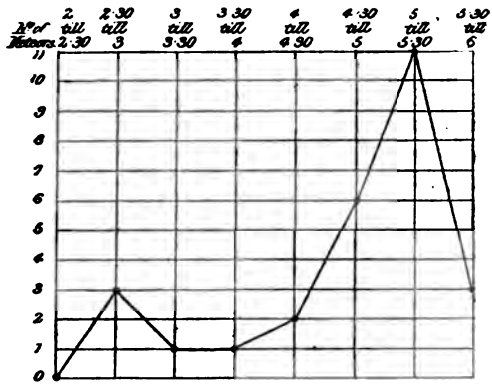
WM. ANDERSON.

G. J. Stoney, Esq., D Sc., F.R.S.

Leonids seen at Madeira on the morning of 1896 November 14.

Greenwich mean times of appearances given. No meteors appeared between $2^h\ 8^m$ A.M. and $2^h\ 38^m$.

Time.	No. of Meteors.	Direction.	Time.	No. of Meteors.	Direction.
2.38 A.M.	1	Line of sight.	5.4 A.M.	2	S.W.
2.40	1	S.W.	5.6	1	S.W.
2.51	1	S.	5.10	1	N.E.
3.9	1	S.W.	5.14	1	N.E.
3.50	1	S.	5.17	1	N.E.
4.8	1	E.	5.18	1	E.
4.23	1	S.E.	5.20	1	S.E.
4.47	1	E.	5.25	1	S.W.
4.51	1	S.	5.30	1	E.
4.54	1	S.E.	5.44	1	S.W.
4 55	1	S.	5.45	1	N.E.
4.57	1	E.	5.53	1	S.E.
4 59	1	S.W.	6.2	1	S.E.
5.3	1	S.W.	6.6	1	E.



Distribution in time of the foregoing *Leonids*.

c/o Kilburn & Co., Calcutta:
1896 November 18.

DEAR SIR,—Re *Leonids*. On November 14 I watched this shower from the time of rising till 16^h Calcutta Local Time (4 A.M. Sunday). Up till 14^h I was only keeping a casual look-out, as I was at my telescope, but till then there were very few meteors visible, and only one bright one from *Leo*.

Between 14^h 30^m and 16^h there were altogether twenty-seven meteors that I saw. Of these twelve came from the *Leonid* radiant, which was as near as I could judge 21° × 152°.

Nine of these twelve were about −1 magnitude, and they were, with exception of two, brilliant yellow with streaks lasting some time. The two exceptions were the brightest of all and

brilliant purple white, like an electric arc. These two appeared at $15^h\ 15^m$ and $15^h\ 18^m$.

They came from the direction of the radiant, but being parallel I could not tell whether they belonged to the shower.

Many of the other meteors noticed came from a point in *Leo*, but they were not so bright, and had not lasting streaks.

Yours faithfully,

J. WILLOUGHBY MEARES.

Ephemeris of the Leonids; with Introductory Remarks by G. Johnstone Stoney, M.A., D.Sc., F.R.S.

The *Leonids* are extended in the form of a stream along their orbit, the dense part of the stream being about 100,000 miles across, and of such length that it takes between one and two years—probably nearly two years—to pass each point. It is at present advancing towards perihelion, and is therefore lengthening out.

The following Ephemeris is of that situation in the stream through which the Earth passed in 1866. It has been computed from Adams's "Elements" (*Monthly Notices* of the Royal Astronomical Society for 1867 April, p. 250) by applying to the orbit the mean advance in longitude of its node, but without further taking into account the perturbations which *Jupiter*, *Saturn*, and *Uranus* have impressed upon the orbit since 1866. It was judged to be useless to attempt greater accuracy, since Professor Adams's elements are themselves uncertain within considerable limits, owing to the very discordant determinations of the radiant point which he had to make the starting point of his calculations. In fact the differences between the individual determinations and their mean ranged up to as much as a whole degree in both Right Ascension and Declination.

Nevertheless, it is hoped that the Ephemeris will be sufficient for the use for which it is intended—viz. to enable astronomers to make their first attempt next spring to obtain a photograph of the meteors while at a distance in the open sky. It will be seen from the Ephemeris that next spring they will be nearly as far off as *Saturn*, whose crape ring (formed of bodies separated like the meteors at a distance from one another) is visible at the ansæ, under favourable circumstances, in observations which are mere eye observations, and notwithstanding the close proximity of bright bodies on all sides. It follows that a very much fainter object might be successfully photographed in a dark part of the sky. Any computation, however, which we can make leads to the conclusion that the meteor stream is so excessively faint that we must not be discouraged if our best efforts on this occasion are unsuccessful. It will in that case be desirable to renew the attempt in the spring of 1898, when the stream will have got nearer to the Sun, and will have become brighter under his beams.

Next spring the stream will be drawn out to an apparent length of at least 5°—possibly 8°—so that if it can be photographed at all it will present the appearance of a streak the whole way across the photographic plate, and about 20″ wide. The uncertainty of the data for the Ephemeris makes it desirable that a full field on each side of that track which is indicated by the Ephemeris shall be explored.

The Ephemeris has been computed by Mr. Wright, of the *Nautical Almanac* Office, under Dr. Downing's special direction, which he most kindly gave; and the cost of making the calculations has been defrayed out of the Donation Fund of the Royal Society.

It is probable that no observations can be made next January, owing to the low position of the swarm in the eastern sky and the approach of dawn, nor in the middles of the succeeding months on account of moonlight, but in the early and late portions of February, March, and April everything will be favourable. The position of the swarm will become more convenient for observation as the season advances, until in April the best conditions will prevail. Soon after that twilight will be troublesome.

Approximate Ephemeris of the Leonids for the first four months of 1897.

Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.	Greenwich Midnight.	Right Ascension.	Decl.	Log. of Dist. from Earth.
1897.	h m s	° ′		1897.	h m s	° ′	
Jan. 1	14 28 19	S 8 39	0·9976	Jan. 22	14 30 1	S 8 29	0·9768
2	14 28 28	8 39	0·9967	23	14 30 1	8 28	0·9757
3	14 28 36	8 39	0·9957	24	14 30 1	8 27	0·9747
4	14 28 44	8 39	0·9948	25	14 30 1	8 26	0·9736
5	14 28 52	8 39	0·9938	26	14 30 0	8 25	0·9726
6	14 28 59	8 38	0·9929	27	14 29 59	8 24	0·9715
7	14 29 5	8 38	0·9919	28	14 29 57	8 23	0·9704
8	14 29 12	8 38	0·9909	29	14 29 55	8 22	0·9694
9	14 29 18	8 37	0·9900	30	14 29 52	8 20	0·9683
10	14 29 24	8 37	0·9890	31	14 29 50	8 19	0·9672
11	14 29 29	8 37	0·9880	Feb. 1	14 29 47	8 18	0·9662
12	14 29 34	8 36	0·9870	2	14 29 43	8 17	0·9651
13	14 29 38	8 36	0·9860	3	14 29 38	8 15	0·9640
14	14 29 42	8 35	0·9850	4	14 29 33	8 14	0·9630
15	14 29 46	8 34	0·9840	5	14 29 27	8 12	0·9619
16	14 29 49	8 34	0·9830	6	14 29 22	8 11	0·9608
17	14 29 52	8 33	0·9820	7	14 29 16	8 9	0·9598
18	14 29 54	8 32	0·9809	8	14 29 9	8 8	0·9587
19	14 29 56	8 32	0·9799	9	14 29 2	8 6	0·9576
20	14 29 58	8 31	0·9789	10	14 28 54	8 4	0·9565
21	14 30 0	8 30	0·9778	11	14 28 46	8 3	0·9555

Greenwich Midnight. 1897.	Right Ascension. h m s	Decl. ° ′	Log. of Dist. from Earth.	Greenwich Midnight. 1897.	Right Ascension. h m s	Decl. ° ′	Log. of Dist. from Earth.
Feb. 12	14 28 38	S 8 1	0·9544	Mar. 24	14 16 48	S 6 22	0·9164
13	14 28 29	7 59	0·9533	25	14 16 22	6 19	0·9157
14	14 28 19	7 58	0·9523	26	14 15 55	6 16	0·9150
15	14 28 9	7 56	0·9512	27	14 15 28	6 12	0·9143
16	14 27 59	7 54	0·9501	28	14 15 1	6 9	0·9136
17	14 27 48	7 52	0·9491	29	14 14 33	6 6	0·9129
18	14 27 37	7 50	0·9480	30	14 14 5	6 3	0·9122
19	14 27 25	7 48	0·9470	31	14 13 37	6 0	0·9115
20	14 27 13	7 46	0·9459	Apr. 1	14 13 9	5 57	0·9109
21	14 27 0	7 44	0·9449	2	14 12 41	5 53	0·9103
22	14 26 47	7 41	0·9438	3	14 12 12	5 50	0·9097
23	14 26 34	7 39	0·9428	4	14 11 43	5 47	0·9091
24	14 26 20	7 37	0·9418	5	14 11 14	5 44	0·9085
25	14 26 5	7 35	0·9408	6	14 10 45	5 40	0·9079
26	14 25 50	7 33	0·9398	7	14 10 15	5 37	0·9074
27	14 25 35	7 30	0·9388	8	14 9 45	5 34	0·9069
28	14 25 19	7 28	0·9378	9	14 9 15	5 31	0·9064
Mar. 1	14 25 3	7 25	0·9368	10	14 8 45	5 27	0·9059
2	14 24 46	7 23	0·9358	11	14 8 15	5 24	0·9054
3	14 24 28	7 21	0·9348	12	14 7 45	5 21	0·9050
4	14 24 10	7 18	0·9338	13	14 7 14	5 18	0·9045
5	14 23 52	7 16	0·9329	14	14 6 43	5 14	0·9041
6	14 23 33	7 13	0·9319	15	14 6 12	5 11	0·9037
7	14 23 14	7 10	0·9310	16	14 5 41	5 8	0·9033
8	14 22 55	7 8	0·9300	17	14 5 10	5 5	0·9029
9	14 22 35	7 5	0·9291	18	14 4 39	5 1	0·9026
10	14 22 15	7 3	0·9282	19	14 4 7	4 58	0·9023
11	14 21 54	7 0	0·9273	20	14 3 36	4 55	0·9020
12	14 21 33	6 57	0·9264	21	14 3 4	4 52	0·9017
13	14 21 11	6 54	0·9255	22	14 2 32	4 48	0·9014
14	14 20 49	6 51	0·9246	23	14 2 1	4 45	0·9011
15	14 20 27	6 49	0·9237	24	14 1 30	4 42	0·9009
16	14 20 4	6 46	0·9229	25	14 0 58	4 39	0·9007
17	14 19 41	6 43	0·9220	26	14 0 27	4 36	0·9005
18	14 19 17	6 40	0·9212	27	13 59 56	4 33	0·9003
19	14 18 53	6 37	0·9203	28	13 59 24	4 29	0·9001
20	14 18 29	6 34	0·9195	29	13 58 53	4 26	0·9000
21	14 18 4	6 31	0·9187	30	13 58 22	4 23	0·8998
22	14 17 39	6 28	0·9179	May 1	13 57 50	4 20	0·8997
23	14 17 14	6 25	0·9172				

Observations of the Leonid Meteors, 1896, *at the Oxford University Observatory.*

(*Communicated by H. H. Turner, M.A., B.Sc., Director.*)

On November 13 the night was thickly overcast with fog, and no meteors were seen.

On November 14 a watch was kept by Mr. F. A. Bellamy and Mr. F. C. H. Carpenter from 9^h till 16^h.

Mr. Carpenter commenced to watch at $11^h\ 15^m$ for any meteors that might appear about the constellation *Leo*, with instructions to note the number counted every quarter of an hour, and to locate any specially bright ones. None were seen from $11^h\ 15^m$ to 12^h, individual meteors were seen at $12^h\ 4^m$, $13^h\ 7^m$, $13^h\ 13^m$, and $13^h\ 58^m$; at $14^h\ 15^m$ the sky became overcast and remained so till $15^h\ 30^m$. Cloud was frequent throughout the period of watch.

Preparations were made by Mr. F. A. Bellamy to photograph the radiant point. Two cameras were fixed to the telescope in the De la Rue dome, and one to the Astrographic telescope; a plate was also exposed in the latter telescope; both telescopes were pointed at R.A. 10^h and Dec. $+20°$. No meteor tracks were found on the plates.

Cloudy weather with drizzling rain prevented any attempt being made to photograph the *Andromedes* on November 27.

The Aurora of 1896 *March* 4. By T. W. Backhouse.

The aurora of March 4 was observed here, though not by myself before $10^h\ 57^m$. A ray, probably the same as that noted by Mr. Goatcher at Cambridge, was seen by my secretary as a conspicuous feature, being at $8^h\ 27^m$ G.M.T. almost vertically under the *Pleiades*, pointing to those stars, and reaching, bright, to half, thence gradually fainter to five-sixths their altitude; it had moved slightly and slowly southwards during the previous five minutes. There is uncertainty as to whether this feature was sufficiently inclined to the vertical as seen here to be a true and perfect auroral ray; while at Cambridge the inclination was too great. It is not professed that the inclination is accurately given at either place; but unless there is considerable error in the descriptions it would appear that the phenomenon was a bundle of rays rather than a single one, and that the lower portion was further east than the upper. It is clear that a true auroral ray was seen later in the evening by other observers, according to

the records in the *Monthly Notices* of March last. Anyone who is familiar with the ordinary type of aurora with streamers cannot fail to recognise in most of the accounts contained in that number of the *Notices*, and the drawing by Sir W. J. Herschel on p. 334, a very good description of an auroral display. No doubt Sir W. J. Herschel and others saw the zodiacal light as well, and it was merely a coincidence that the two phenomena were superposed.

Observations of the ray seen here were made at several other places, and one made at York by Mr. J. E. Clark was sufficiently exact for him to use in conjunction with those at Sunderland and Cambridge to calculate the height. He finds that at 8.30 P.M. it was 200 miles above Galway Bay at the top, and 40 miles or less at its base, above a point a quarter of the distance from Louth to Drogheda. With these positions it could not be a simple ray; but if we assume that it was one, and that there was error in the descriptions, and take the mean position, it would still leave the middle of the ray at an altitude of about 120 miles, while the height of the apex would be lowered, and that of the base increased.

Observations of Minor Planets at Windsor, New South Wales.

By John Tebbutt.

The accompanying observations of minor planets during 1896 were made with the filar micrometer on the 8-inch equatorial and in an illuminated field. The differential observations are corrected for refraction, and a small error in the perpendicularity of the micrometer threads. The distance threads of the micrometer are so fine and the planet *Undina* was so faint that considerable difficulty was experienced in this case. On comparing the resulting places of *Calliope* with an approximate ephemeris kindly furnished by Dr. Bauschinger, of Berlin, I found there was a fair agreement except in the case of September 21, 22, 23, when the places depend on star No. 1. The only authority I could find for this star was Arg.-Oeltzen, in which catalogue it is given as No. 300. I was led to suspect that the tabular N.P.D. of this star was about a minute too great, and I accordingly made six comparisons of the star with the clock star β *Ceti* on October 16, the result of which completely confirmed my suspicions. I have therefore adopted the mean place as derived from the equatorial comparisons. *Sappho* was brighter than I expected to find it. The opposition magnitude given in the *Berliner Astronomisches Jahrbuch* for 1898 is 9·3, whereas I regarded it as fully equal to 8·5. I will add that the quantities $p\Delta$ have been computed with an assumed value of the solar parallax $=8''{\cdot}85$.

Date.	Windsor Mean Time.	Planet − Star. Δ R.A.	Δ N.P.D.	No. of Comps.	Planets App. R.A.	Log. $p\Delta$	Planet's App. N.P.D.	Log. $p\Delta$.	Reduction to App. Place R.A.	Reduction to App. Place N.P.D.	Comp. Star.
					(6) *Hebe.*						
1896.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
May 17	9 52 22	+0 24·34	−10 14·1	20	17 0 37·86	9·585*n*	90 34 56·9	0·683	+2·91	+14·5	1
18	9 56 9	−0 25·22	−13 26·3	20	16 59 48·31	9·571*n*	90 31 44·6	0·684	+2·92	+14·4	1
30	9 15 17	+1 7·79	+18 24·3	15	16 48 55·24	9·541*n*	90 7 15·5	0·687	+3·11	+13·5	2
June 1	8 42 31	−0 47·24	+16 59·9	7	16 47 0·23	9·581*n*	90 5 50·8	0·687	+3·13	+13·2	2
5	9 16 4	−4 43·59	+16 42·2	10	16 43 3·93	9·475*n*	90 5 32·6	0·687	+3·18	+12·7	2
5	9 16 4	−1 0·48	+11 35·9	10	16 43 3·95	9·475*n*	90 5 30·5	0·687	+3·17	+12·9	3
10	9 39 25	−1 20·68	+1 1·5	10	16 38 11·29	9·324*n*	90 9 58·5	0·686	+3·22	+12·5	4
10	9 39 25	−2 58·14	+0 21·7	10	16 38 11·09	9·324*n*	90 9 59·6	0·686	+3·22	+12·4	5
11	8 26 43	−2 15·42	+2 30·4	15	16 37 16·56	9·521*n*	90 11 27·3	0·686	+3·23	+12·4	4
11	8 26 43	−3 52·81	+1 50·6	15	16 37 16·43	9·521*n*	90 11 28·4	0·686	+3·23	+12·3	5
13	8 40 54	+3 17·75	+2 58·7	15	16 35 22·33	9·465*n*	90 15 11·5	0·685	+3·23	+12·4	6
14	8 35 5	+2 21·91	+5 10·7	15	16 34 26·50	9·467*n*	90 17 23·4	0·685	+3·24	+12·3	6
15	8 53 51	+1 25·65	+7 37·6	15	16 33 30·24	9·400*n*	90 19 50·2	0·684	+3·24	+12·2	6
16	7 40 6	+0 33·70	+10 6·3	20	16 32 38·30	9·563*n*	90 22 18·8	0·685	+3·25	+12·1	6
					(11) *Parthenope.*						
Apr. 11	9 55 2	+4 4·40	+12 20·5	12	14 47 58·97	9·599*n*	98 16 53·3	0·621	+2·52	+18·7	1
11	9 55 2	+0 36·39	...	12	14 47 59·27	9·599*n*	...	...	+2·52	...	2
12	9 56 49	+3 20·26	+7 20·6	15	14 47 14·85	9·590*n*	98 11 53·4	0·620	+2·54	+18·7	1
12	9 56 49	−0 7·71	...	15	14 47 15·19	9·590*n*	...	...	+2·54	...	2

Date.	Windsor Mean Time.	Planet − Star. Δ R.A.	Δ N.P.D.	No. of Comps.	Planet's App. R.A.	Log. $p\Delta$.	Planet's App. N.P.D.	Log. $p\Delta$.	Reduction to App. Place R.A.	Reduction to App. Place N.P.D.	Comp. Star.
1896.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Apr. 13	10 13 42	+2 34·59	+ 2 17·5	11	14 46 29·20	9·553n	98 6 50·3	0·613	+2·56	+18·7	1
13	10 13 42	−0 53·48	...	11	14 46 29·43	9·553n	...	...	+2·55	...	2
14	10 6 21	+1 48·46	− 2 44·0	10	14 45 43·08	9·558n	98 1 48·8	0·615	+2·57	+18·7	1
14	10 6 21	−3 14·96	+ 3 40·1	10	14 45 43·13	9·558n	98 1 49·9	0·615	+2·57	+18·7	3
15	9 35 44	+1 1·21	− 7 41·0	10	14 44 56·85	9·599n	97 56 51·8	0·625	+2·59	+18·7	1
15	9 35 44	−4 1·28	− 1 15·6	10	14 44 56·82	9·599n	97 56 54·2	0·625	+2·58	+18·7	3
17	9 56 8	+4 33·25	− 2 22·1	7	14 43 18·69	9·551n	97 46 43·0	0·616	+2·62	+18·8	4
17	9 56 8	−5 39·48	...	7	14 43 18·65	9·551n	...	...	+2·61	...	3
18	9 50 28	+3 43·28	− 7 23·5	10	14 42 28·73	9·552n	97 41 41·6	0·617	+2·63	+18·8	4
18	9 50 28	−6 29·43	...	10	14 42 28·71	9·552n	...	...	+2·62	...	3
19	10 22 8	+2 51·15	−12 33·6	10	14 41 36·61	9·473n	97 36 31·5	0·607	+2·64	+18·8	4
23	10 14 26	−2 38·76	− 5 12·7	10	14 38 5·71	9·442n	97 16 36·1	0·608	+2·69	+18·8	5
24	9 22 39	−3 30·95	− 9 56·3	10	14 37 13·53	9·550n	97 11 52·5	0·622	+2·70	+18·8	5
30	10 3 33	−1 28·14	+ 0 29·9	14	14 31 40·27	9·368n	96 43 25·7	0·610	+2·76	+18·8	6
May 1	9 13 14	−2 21·85	− 3 48·6	16	14 30 46·57	9·498n	96 39 7·2	0·621	+2·77	+18·8	6
3	8 52 28	+1 1·52	+ 1 33·1	9	14 28 55·71	9·523n	96 30 29·9	0·626	+2·78	+18·8	7
3	8 52 28	+0 41·59	...	9	14 28 55·87	9·523n	...	...	+2·78	...	8
4	8 41 50	+4 45·57	+ 0 0·8	12	14 28 0·83	9·534n	96 26 19·7	0·628	+2·78	+18·8	9
4	8 41 50	+0 6·51	− 2 38·1	12	14 28 0·71	9·534n	96 26 18·7	0·628	+2·79	+18·8	7
5	9 9 27	+3 49·13	− 4 9·7	10	14 27 4·40	9·459n	96 22 9·1	0·621	+2·79	+18·7	9
5	9 9 27	−0 49·92	...	10	14 27 4·28	9·459n	...	...	+2·79	...	7
6	9 16 56	+2 53·98	− 8 11·4	10	14 26 9·26	9·425n	96 18 7·4	0·619	+2·80	+18·7	9

Date.	Windsor Mean Time.	Planet−Star. Δ R.A.	Δ N.P.D.	No. of Comps.	Planet's App. R.A.	Log. $p\Delta$.	Planet's App. N.P.D.	Log. $p\Delta$.	Reduction to App. Place R.A.	Reduction to App. Place N.P.D.	Comp. Star.
1896.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
May 6	9 16 56	−1 45·12	...	10	14 26 9·099	9·425*n*	...	...	+2·80	...	7
7	9 21 34	+1 59·05	−12 4·9	10	14 25 14·33	9·395*n*	96 14 13·8	0·618	+2·80	+18·6	9
7	9 21 34	−2 39·92	...	10	14 25 14·29	9·395*n*	...	...	+2·80	...	7
8	8 53 40	+1 6·05	−15 47·3	10	14 24 21·34	9·463*n*	96 10 31·4	0·623	+2·81	+18·6	9
8	8 53 40	−3 33·06	...	10	14 24 21·16	9·463*n*	...	...	+2·81	...	7
					(22) *Calliope.*						
Sept. 21	9 40 17	−0 24·64	− 6 7·9	15	0 31 10·37	9·539*n*	108 15 31·2	0·463	+4·27	−28·1	1
22	9 19 47	−1 15·57	− 2 35·1	15	0 30 19·45	9·570*n*	108 19 4·0	0·478	+4·28	−28·1	1
23	9 32 20	−2 8·12	+ 0 52·4	10	0 29 26·90	9·536*n*	108 22 31·6	0·459	+4·28	−28·0	1
26	8 53 37	−0 4·05	−15 40·6	5	0 26 50·88	9·583*n*	108 31 33·9	0·483	+4·33	−27·5	2
27	8 49 11	−0 56·99	−13 1·7	10	0 25 57·95	9·583*n*	108 34 12·9	0·482	+4·34	−27·4	2
27	8 49 11	−1 27·54	...	10	0 25 57·97	9·583*n*	...	...	+4·33	...	3
28	9 0 45	−1 50·44	−10 31·2	13	0 25 4·50	9·552*n*	108 36 40·5	0·463	+4·34	−27·3	2
28	9 0 45	−2 21·02	...	13	0 25 4·50	9·552*n*	...	...	+4·34	...	3
30	8 50 27	−3 35·97	+ 6 17·9	10	0 23 18·99	9·553*n*	108 40 56·9	0·462	+4·35	−27·2	2
30	8 50 27	−4 6·46	...	10	0 23 19·07	9·553*n*	...	...	+4·35	...	3
Oct. 2	9 35 35	−5 23·05	− 2 52·0	6	0 21 31·92	9·412*n*	108 44 23·0	0·408	+4·37	−27·0	2
2	9 35 35	−5 53 56	...	6	0 21 31·99	9·412*n*	...	...	+4·37	...	3

Date.	Windsor Mean Time.	Planet − Star. Δ R.A.	Δ N.P.D.	No. of Compn.	Planet's App. R.A.	Log. $p\Delta$.	Planet's App. N.P.D.	Log. $p\Delta$.	Reduction to App. Place R.A.	N.P.D.	Comp. Star.
					(61) *Danaë.*						
1896.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Aug. 11	10 32 9	+5 41·60	+19 28·0	10	22 14 45·85	9·469*n*	105 56 4·1	0·481	+4·12	−18·5	1
12	9 53 32	+4 41·52	+16 47·9	10	22 13 45·78	9·548*n*	105 53 24·0	0·508	+4·13	−18·5	1
18	11 16 22	−1 44·09	− 0 43·4	10	22 7 20·24	9·131*n*	105 35 52·4	0·444	+4·20	−18·8	1
19	10 31 34	−2 46·63	− 3 42·7	10	22 6 17·71	9·339*n*	105 32 53·1	0·463	+4·21	−18·8	1
24	9 2 36	−1 3·83	+17 22·4	15	22 0 57·66	9·528*n*	105 16 53·7	0·511	+4·25	−18·3	2
26	9 47 23	−3 14·07	+10 20·6	10	21 58 47·43	9·374*n*	105 9 51·9	0·476	+4·26	−18·3	2
26	9 47 23	−0 6·75	+13 9·1	10	21 58 47·66	9·374*n*	105 9 51·5	0·476	+4·26	−18·0	3
29	9 0 2	−6 20·95	− 0 22·9	10	21 55 40·57	9·474*n*	104 59 8·4	0·495	+4·28	−18·3	2
29	9 0 2	−3 13·66	+ 2 24·6	10	21 55 40·77	9·474*n*	104 59 7·0	0·495	+4·28	−18·0	3
					(80) *Sappho.*						
Oct. 19	10 47 7	−2 36·40	− 6 56·4	14	1 44 55·59	9·145*n*	75 30 36·3	0·812	+4·40	−28·3	1
20	10 34 17	−3 22·32	+ 5 41·2	10	1 44 9·68	9·196*n*	75 43 13·8	0·810	+4·41	−28·4	1
20	10 34 17	−1 35·17	− 1 55·0	10	1 44 9·27	9·196*n*	75 43 12·7	0·810	+4·40	−28·4	2
21	10 0 23	−4 7·38	...	10	1 43 24·62	9·336*n*	...	...	+4·41	...	1
21	10 0 23	−2 20·22	+10 32·9	10	1 43 24·23	9·336*n*	75 55 40·6	0·802	+4·41	−28·4	2
					(92) *Undina.*						
Oct. 5	8 57 35	+2 0·86	− 4 10·2	16	0 47 0·14	9·532*n*	101 7 37·9	0·572	+4·27	−28·0	1
9	9 1 17	−0 56·27	+10 57·6	16	0 44 3·03	9·481*n*	101 22 46·0	0·558	+4·29	−27·7	1
10	9 50 5	−1 41·33	+14 24·4	14	0 43 17·98	9·305*n*	101 26 12·8	0·536	+4·30	−27·7	1
11	10 22 11	−2 25·45	+17 39·6	9	0 42 33·86	9·100*n*	101 29 28·1	0·525	+4·30	−27·6	1

Date.	Windsor Mean Time.	Planet−Star. Δ R.A.	Δ N.P.D.	No. of Comps.	Planet's App. R.A.	Log. $p\Delta$.	Planet's App. N.P.D.	Log. $p\Delta$.	Reduction to App. Place R.A.	Reduction to App. Place N.P.D.	Comp. Star.
					(140) *Siwa.*						
1896.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
July 25	9 42 0	−1 36·31	−14 36·6	10	19 50 52·11	9·405*n*	112 17 8·4	0·311	+4·30	−4·6	1
25	9 42 0	+2 36·54	−12 20·5	10	19 50 52·03	9·405*n*	112 17 8·7	0·311	+4·30	−4·7	2
26	9 46 41	−2 24·44	−10 26·4	8	19 50 3·99	9·370*n*	112 21 18·6	0·298	+4·31	−4·6	1
26	9 46 41	−3 24·73	− 8 10·4	8	19 50 3·85	9·370*n*	112 21 18·8	0·298	+4·31	−4·7	2
27	8 45 40	−3 9·53	− 6 30·8	10	19 49 18·91	9·537*n*	112 25 14·2	0·373	+4·32	−4·6	1
27	8 45 40	−4 9·86	− 4 14·8	10	19 49 18·73	9·537*n*	112 25 14·4	0·373	+4·32	−4·7	2
28	8 22 14	−3 55·39	− 2 33·5	10	18 48 33·06	9·576*n*	112 29 11·5	0·399	+4·33	−4·6	1
28	8 22 14	−4 55·76	− 0 16·9	10	19 48 32·84	9·576*n*	112 29 12·3	0·399	+4·33	−4·7	2
29	8 57 3	−4 42·57	+ 1 30·7	8	19 47 45·89	9·486*n*	112 33 15·7	0·339	+4·34	−4·6	1
29	8 57 3	−5 42·88	+ 3 46·4	8	19 47 45·72	9·486*n*	112 33 15·6	0·339	+4·33	−4·7	2
Aug. 1	8 34 9	+1 25·12	−17 49·1	10	19 45 33·54	9·519*n*	112 44 35·1	0·347	+4·36	−3·6	3
1	8 34 9	−4 58·73	...	10	19 45 33·39	9·510*n*	...	...	+4·37	...	4
2	8 1 13	+0 43·87	−14 16·1	10	19 44 52·30	9·572*n*	112 48 8·1	0·389	+4·37	−3·6	3
2	8 1 13	−5 39·98	...	10	19 44 52·14	9·572*n*	...	...	+4·37	...	4
3	9 12 15	...	−10 33·6	7	...	...	112 51 50·6	0·279	...	−3·6	3
3	9 12 15	−6 23·33	− 7 24·5	7	19 44 8·80	9·361*n*	112 51 51·2	0·279	+4·38	−4·3	4
4	8 39 15	−0 38·88	− 7 11·0	8	19 43 29·55	9·459*n*	112 55 13·2	0·315	+4·37	−3·6	3
4	8 39 15	−7 2·62	− 4 2·0	8	19 43 29·51	9·459*n*	112 55 13·7	0·315	+4·38	−4·3	4
5	8 21 57	−1 16·91	− 3 52·4	10	19 42 51·53	9·495*n*	112 58 31·8	0·332	+4·38	−3·6	3

Adopted Mean Places of the Comparison Stars for 1896·0.

Star.	R.A.	N.P.D.	Authorities.
			(6) *Hebe.*
	h m s	° ′ ″	
1	17 0 10·61	90 44 56·5	Lamont 5,468, Göttingen 4,178, Glasgow 1870, 4,204, Greenwich 1880, 2,665, Radcliffe 1890, 4.446.
2	16 47 44·34	89 48 37·7	Lamont 5,371, Göttingen 4,108, Yarnall, 7,114, Schjellerup 6,007, Glasgow 1870, 4,162, Glasgow 1890, 1,458, Cincinnati 1,374, Radcliffe 1890, 4,385.
3	16 44 1·26	89 53 41·7	Lamont 5,337, Göttingen 4,085, Glasgow 1870, 4,143.
4	16 39 28·75	90 8 44·5	Lamont 5,294, Göttingen 4,052, Radcliffe 1890, 4,356.
5	16 41 6·01	90 9 25·5	Radcliffe 1890, 4.364.
6	16 32 1·35	90 12 0·4	Göttingen 4,011, Radcliffe 1890, 4,315.
			(11) *Parthenope.*
1	14 43 52·05	98 4 14·1	Radcliffe 1890, 3,831.
2	14 47 20·36	98 16 8·4	Lalande 27,076.
3	14 48 55·52	97 57 51·1	Radcliffe 1890, 3,848.
4	14 38 42·82	97 48 46·3	Radcliffe 1890, 3,807.
5	14 40 41·78	97 21 30·0	Radcliffe 1890, 3,819.
6	14 33 5·65	96 42 37·0	Radcliffe 1890, 3,786.
7	14 27 51·41	96 28 38·0	Radcliffe 1890, 3,766.
8	14 28 11·50	96 24 40·2	Lalande 26,549, Lamont 1,715.
9	14 23 12·48	96 26 0·1	Greenwich 1880, 2,243, Stone 7,891, Radcliffe 1890, 3 751.

Star.	R.A.	N.P.D.	Authority.
			(22) *Calliope.*
	h m s	° ′ ″	
1	0 31 30·74	108 22 7·2	Six filar-micrometer Comps. with β Ceti, 1896 Oct. 16.
2	0 26 50·60	108 47 42·0	Arg.-Oeltzen 245–6, Radcliffe 1893, 101.
3	0 27 21·18	108 41 0·4	Arg.-Oeltzen 248–9.
			(61) *Danaë.*
1	22 9 0·13	105 36 54·6	Yarnall$_3$ 10,026, Radcliffe 1890, 5,980.
2	22 1 57·24	104 59 49·6	Lalande 43,108–9, Lamont 1,488, Arg.-Oeltzen 21,904, Yarnall$_3$ 9,957, Radcliffe 1890, 5,949.
3	21 58 50·15	104 57 0·4	Lalande 43,009, Lamont 1,486.
			(80) *Sappho.*
1	1 47 27·59	75 38 1·0	Yarnall$_3$ 900.
2	1 45 40·04	75 45 36·1	Yarnall$_3$ 884.
			(92) *Undina.*
1	0 44 55·01	101 12 16·1	Radcliffe 1860, 91, Yarnall$_3$ 436, Greenwich 1864, 99, Quetelet 332, Arg. Gen. Cat. 757, Stone 328, Radcliffe 1890, 168.
			140 *Siwa.*
1	19 52 24·12	112 31 49·6	Arg.-Oeltzen 20,116, Arg. Gen. Cat. 27,328.
2	19 53 24·27	112 29 33·9	Arg.-Oeltzen 20,131, Arg. Gen. Cat. 27,360, Radcliffe 1890, 5,344.
3	19 44 4·06	113 2 27·8	Arg.-Oeltzen 19,992–3, Arg. Gen. Cat. 27,150, Radcliffe 1890, 5,298.
4	19 50 27·75	112 59 20·4	Arg. Gen. Cat. 27,286.

Private Observatory, The Peninsula, Windsor, N.S. Wales:
1896 *October* 29.

Observations of Comet f 1896 (*Perrine*) *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks Equatorial, aperture 6·7 inches, by taking transits over two cross-wires to right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55.

Greenwich Mean Solar Time.					Observer.	☄−✱R.A.	Corr. for Refraction.	Log. factor of Parallax.	☄−✱N.P.D.	Corr. for Refraction.	Log. factor of Parallax.	No. of Comps.	Apparent R.A. of ☄	Apparent N.P.D. of ☄	Comp. Star.
1896.	d	h	m	s		m s	s		′ ″	″			h m s	° ′ ″	
Nov.	29	7	22	12	B.	+0 34·54	0·00	9·5122	−1 24·5	0·0	0·8129	4	19 54 9·76	82 44 21·9	*a*
	30	6	9	59	C. D.	−1 12·66	+0·01	9·4122	−6 45·5	−0·1	0·8046	5	19 53 44·03	83 13 34·9	*b*
	30	6	14	4	,,	−1 8·66	−0·01	9·4201	+9 37·5	+0·3	0·8052	4	19 53 43·54	83 13 31·8	*c*
Dec.	4	5	30	18	,,	−0 1·45	−0·01	9·3617	+7 1·5	+0·1	0·8132	3	19 52 11·74	85 10 48·0	*d*
	4	5	48	32	,,	−0 42·91	+0·01	9·4027	−9 26·7	−0·3	0·8149	3	19 52 12 63	85 11 3·4	*e*

Notes.

The observations are corrected for refraction, but not for parallax. They are also corrected for the error of inclination of the wires and for the motion of the Comet.

November 29.—The Comet had a fairly defined nucleus.

November 30.—The Comet had a well-defined nucleus.

December 4.—There was no nucleus visible. The presence of a small star a little south preceding the centre of the Comet made observation difficult.

The initials B. and C. D. are those of Mr. Bryant and Mr. Davidson respectively.

Comparison Stars.

	Star's Name.	Assumed R.A. 1896·0. h m s	Assumed N.P.D. 1896·0. ° ′ ″	Authority.
a	W.B. XIX. 1294	19 53 32·88	82 45 56·2	Munich Catalogue 1880.
b	Lalande 38148	19 54 54·32	83 20 30·2	Yarnall, Munich and Bonn Observations, vol. vi.
c	W.B. XIX. 1321	19 54 49·86	83 4 3·8	Brussels 1865, and Bonn Observations, vol. vi.
d	B.D. +4° No. 4286	19 52 10·83	85 3 54·9	Albany Astr. Gesell, Munich, and Schjellerup's Catalogues.
e	B.D. +4° No. 4292	19 52 53·15	85 20 38·9	Albany Astr. Gesell Catalogue.

Note.—In Lalande's Catalogue the N.P.D. of 38144 belongs to 38148, and *vice versa*.

Royal Observatory, Greenwich:
1896 *December* 11.

Observation of Brooks' Periodic Comet 1896 *c* (1889 V) *at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observation was made with the 10-inch Barclay Equatorial, using the ring-micrometer with power 100.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log. $(q \times \Delta)$.
1896.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″	
Oct. 9	9 56 12	23 7 11	R.	+1 19·39	−1 11·2	9	22 9 4·02	+0·08	8·9786	106 26 44·6	7·0	0·9098

Observer's Remarks.

The Comet is about 1′ in diameter, and has a faint but distinct nucleus.

Observer : Mr. W. H. Robinson.

Assumed Place of the Comparison Star.

Mean R.A. 1896.	Reduction to Apparent R.A.	Mean N.P.D. 1896.	Reduction to Apparent N.P.D.	Authority.
h m s	s	° ′ ″	″	
22 7 40·45	+4·18	106 28 12·9	−17·1	Radcliffe Transit-circle observation, 1896 October 31.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distance, Δ, is taken from the *Astronomische Nachrichten*, No. 3,378.

Radcliffe Observatory, Oxford:
1896 *December* 10.

Ephemeris for Physical Observations of the Moon, 1897 January to August. By A. Marth.

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Jan. 7	317·12	−0·75	+5·07	−2·74	5·76	241·6
8	329·30	·73	4·26	4·00	5·84	226·7
9	341·47	·71	3·22	5·06	6·00	212·4
10	353·63	·69	2·03	5·88	6·22	198·9
11	5·79	·66	+0·75	6·44	6·48	186·6
12	17·94	·64	−0·53	6·73	6·75	175·5
13	30·09	−0·61	−1·73	−6·72	6·94	165·6
14	42·23	·58	2·80	6·42	7·00	156·5
15	54·37	·55	3·69	5·83	6·89	147·8
16	66·50	·52	4·34	4·95	6·58	138·8
17	78·63	·49	4·75	3·80	6·08	128·7
18	90·76	·46	4·91	2·43	5·48	116·4
19	102·89	−0·43	−4·81	−0·90	4·89	100·6
20	115·02	·40	4·48	+0·70	4·54	81·1
21	127·15	·37	3·95	2·29	4·56	59·8
22	139·29	·34	3·23	3·77	4·96	40·6
23	151·43	·31	2·37	5·03	5·56	25·2
24	163·58	·28	1·41	5·99	6·15	13·2
25	175·73	−0·25	−0·38	+6·60	6·61	3·3
Feb. 6	321·95	+0·06	+2·02	−5·69	6·04	199·5
7	334·13	·09	+0·86	6·34	6·40	187·7
8	346·30	·11	−0·40	6·71	6·72	176·6
9	358·47	·14	1·67	6·80	7·00	166·3
10	10·64	·17	2·89	6·59	7·19	156·5
11	22·80	·20	3·98	6·09	7·27	147·0
12	34·95	+0·23	−4·87	−5·31	7·20	137·6
13	47·10	·26	5·50	4·26	6·95	127·8
14	59·24	·29	5·82	2·97	6·53	117·1
15	71·38	·32	5·80	−1·48	5·98	104·4
16	83·52	·35	5·42	+0·12	5·42	88·7
17	95·65	·39	4·70	1·77	5·02	69·3
18	107·79	+0·42	−3·70	+3·32	4·96	48·0
19	119·93	·45	2·45	4·67	5·29	27·6

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Feb. 20	132·07	+0·48	−1·10	5·77	5·87	10·7
21	144·22	·50	+0·29	6·47	6·48	357·5
22	156·38	·53	1·60	6·77	6·95	346·8
23	168·54	·56	2·76	6·64	7·18	337·5
24	180·70	+0·58	+3·72	+6·10	7·14	328·8
Mar. 6	302 68	+0·80	+1·13	−6·10	6·21	190·4
7	314·88	0·83	−0·06	6·55	6·55	179·5
8	327·08	0·85	1·32	6·71	6·84	168·9
9	339·27	0·87	2·60	6·58	7·08	158·5
10	351·45	0·89	3·85	6·17	7·27	148·1
11	3·63	+0·92	−5·01	−5·49	7·42	137·7
12	15·81	0 94	5·96	4·54	7·49	127·4
13	27·98	0·97	6·66	3·36	7·46	116·9
14	40·15	0·99	7·02	1·99	7·29	105·8
15	52·31	1·01	6·98	−0·46	7·00	93·8
16	64·47	+1·04	−6·50	+1·14	6·60	80·1
17	76·62	1·06	5·57	2·71	6·19	64·0
18	88·77	1 09	4·24	4·16	5·93	45·5
19	100 92	1·11	2·58	5·35	5·94	25·6
20	113·07	1·13	−0·76	6·19	6·24	6·9
21	125·22	+1·15	+1·10	+6·61	6·70	350·6
22	137·38	1·17	2·80	6·58	6·14	337·0
23	149·55	1·19	4·25	6·11	7·44	325·4
24	161·72	1·20	5·34	5·28	7·50	314·8
25	173·90	+1·21	+6·04	+3·86	7·33	304·6
Apr. 5	308·23	+1·35	−1·79	−6·48	6·72	164·6
6	320·44	1·37	3·09	6·12	6·85	153·3
7	332·65	1·38	4·35	5·49	7·01	141·7
8	344·86	1·39	5·53	4·62	7·20	130·0
9	357·06	1·40	6·55	3·52	7·43	118·3
10	9·25	1·42	7·33	2·24	7·66	107·0
11	21·44	+1·43	−7·79	−0·81	7·83	96·0
12	33·63	1·44	7·84	+0·70	7·87	84·9
13	45·81	1·45	7·42	2·23	7·74	73·2
14	57·98	1·46	6·50	3·67	7·46	60·4
15	70·15	1·47	5·09	4·92	7·07	45·8

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1807.	°	°	°	°	°	°
Apr. 16	82·32	+1·48	−3·27	+5·87	6·71	29·0
17	94·48	1·49	−1·18	6·42	6·53	10·4
18	106·65	1·50	+0·98	6·52	6·59	351·5
19	118·82	1·50	3·02	6·15	6·85	333·9
20	130·99	1·51	4·76	5·38	7·18	318·6
21	143·17	1·51	6·08	4·27	7·42	305·1
22	155·36	1·51	6·93	2·93	7·52	293·0
23	167·55	+1·51	+7·32	+1·46	7·46	281·3
May 5	314·25	+1·51	−4·38	−4·63	6·32	136·3
6	326·48	1·51	5·52	3·56	6·56	122·9
7	338·71	1·51	6·52	2·32	6·92	109·6
8	350·93	1·51	7·30	−0·94	7·36	97·3
9	3·14	1·51	7·80	+0·52	7·82	86·2
10	15·35	1·51	−8·04	1·99	8·28	76·0
11	27·55	1·50	7·63	3·40	8·35	65·9
12	39·74	1·50	6·83	4·65	8·26	55·6
13	51·93	1·50	5·54	5·66	7·92	44·3
14	64·12	1·49	3·81	6·31	7·37	31·0
15	76·30	+1·48	−1·77	+6·54	6·78	15·0
16	88·48	1·48	+0·42	6·31	6·32	356·2
17	100·66	1·47	2·55	5·63	6·18	335·7
18	112·84	1·46	4·43	4·56	6·36	315·9
19	125·02	1·45	5·92	3·21	6·73	298·5
20	137·21	1·43	6·93	1·70	7·13	283·8
21	149·41	1·42	7·45	+0·14	7·45	271·0
22	161·62	1·41	7·50	−1·38	7·62	259·5
23	173·83	1·40	7·15	2·79	7·67	248·6
24	186·04	+1·38	+6·48	−4·02	7·62	238·1
June 4	320·68	+1·25	−6·01	−1·04	6·10	99·8
5	332·92	1·23	6·68	+0·42	6·85	86·4
6	345·15	1·22	7·07	1·88	7·49	75·1
7	357·37	1·21	7·19	3·28	7·90	65·4
8	9·59	1·19	6·91	4·54	8·26	56·5
9	21·80	1·18	6·24	5·58	8·36	48·1
10	34·01	1·16	5·14	6·30	8·12	39·0
11	46·21	1·14	3·65	6·64	7·57	28·7

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
June 12	58·41	+1·12	−1·90	+6·54	6·81	16·1
13	70·60	1·10	+0·07	5·99	5·99	359·3
14	82·79	1·08	2·01	5·02	5·41	338·3
15	94·98	1·06	3·77	3·72	5·30	314·6
16	107·17	1·04	5·23	2·19	5·66	292·8
17	119·36	1·01	6·27	+0·56	6·30	275·1
18	131·56	0·99	6·87	−1·05	6·95	261·3
19	143·76	0·97	7·02	2·56	7·47	249·9
20	155·97	0·94	6·77	3·89	7·80	240·0
21	168·18	0·92	6·17	4·99	7·93	230·9
22	180·40	+0·90	+5·30	−5·83	7·87	222·1
July 6	351·80	+0·60	−5·46	+5·52	7·76	44·6
7	4·02	0·58	4·78	6·30	7·90	37·0
8	16·24	0·55	3·80	6·71	7·71	29·4
9	28·45	0·53	2·56	6·72	7·19	20·8
10	40·66	0·50	−1·13	+6·31	6·41	10·1
11	52·86	0·47	+0·41	5·47	5·49	355·7
12	65·05	+0·45	1·94	4·28	4·70	335·6
13	77·24	0·42	3·36	2·81	4·38	310·0
14	89·43	0·39	4·55	+1·18	4·70	284·6
15	101·62	0·36	5·44	−0·49	5·46	264·9
16	113·82	0·33	5·97	2·09	6·32	250·7
17	126·01	0·30	6·03	3·53	6·98	239·6
18	138·21	+0·27	+5·92	4·74	7·58	231·2
19	150·42	0·24	5·38	5·69	7·83	223·3
20	162·63	0·21	4·57	−6·36	7·82	215 6
21	174·85	0·18	3·53	6·72	7·59	207·6
22	187·07	0·16	2·35	6·77	7·17	199·1
23	199·30	0·13	+1·09	6·66	6·75	189·3
24	211·53	0·10	−0·18	6·06	6·06	178·3
25	223·77	+0·08	−1·40	−5·29	5·47	165·2
Aug. 5	358·43	−0·18	−1·80	+6·79	7·02	14·8
6	10·64	0·21	−0·74	6·47	6·51	6·5
7	22·85	0·24	+0·43	5·75	5·76	355·7
8	35·05	0·27	1·55	4·67	4·92	341·7
9	47·25	0·30	2·63	3·31	4·23	321·6
10	59·44	0·33	3·58	1·76	3·99	296·2
11	71·63	0·36	4·36	+0·11	4·36	271·5

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Aug. 12	83·81	−0·39	+4·91	−1·51	5·14	252·9
13	96·00	0·42	5·21	3·02	6·02	239·9
14	108·18	0·45	5·23	4·33	6·78	230·3
15	120·37	0·48	4·96	5·38	7·31	222·6
16	132·56	0·50	4·41	6·15	7·56	215·5
17	144·76	0·53	3·60	6·61	7·52	208·4
18	156·96	0·56	2·58	−6·77	7 24	200·8
19	169·16	0·58	1·41	6·63	6·78	191·9
20	181·37	0·61	+0·15	6·20	6·21	181·3
21	193·59	0·63	−1·13	5·51	5·63	168·4
22	218·82	0·65	2·35	4·58	5·14	152·9
23	230·05	0·67	3·44	3·43	4·85	135·0
24	242·29	−0·69	−4·30	−2·10	4·78	116·1

In the general list of published and properly timed lunar photographs and sketches, referred to in the last ephemeris, *Monthly Notices*, vol. lvi. p. 159, the photographs will be arranged according to the Sun's selenographical positions, and the topocentric librations or the selenographical positions of the places of observing will be added, so that the varying effects of the foreshortening may be duly taken into account. For the present I must content myself with making an addition to the old list published in vol. li.

The photographs now inserted are those published in vol. xxxii. part 1 of the Annals of the Harvard College Observatory, those in vol. iii. of the Publications of the Lick Observatory, and the few in *Knowledge*, of which the times are known. The Lick references are :

	Sel. Long. of the Sun.	Lat.	Pacific Standard T.	h	m	s	
	″	°					
Lick 1	15·72	+1·15	1891 July 14	8	12	26·5	Lick, vol. iii.
2	33·98	+0·97	1891 Oct. 12	7	30	54·5	,,
3	115·43	+1·51	1890 Aug. 31	14	27		,,
4	172·48	−0·91	1895 Oct. 9	16	36	20	Knowl. 95 Oct. Dec.
5	173·00	−0·35	1892 Nov. 10	15	52	41	Lick, vol. iii.
6	184·77	−0·93	1895 Oct. 10	16	49	13 8	Plate 1 of Obs. Atlas.
7	190·10	+1·37	1891 July 28	15	49	16	Lick, vol. iii.

The time of the Paris photograph in *Knowledge* for '95 June and '96 April should be 1894 March 14, $7^h\ 4^m{\cdot}5$ Paris mean time, as M. Puiseux has kindly informed me, the inserted time being approximately sidereal. The sketches referred to in the list are found in the reports of the Lunar Section of the British Astronomical Association, or in the *Observatory* of 1896.

Sun's Colong. ☉'s Lat.	Sun's Colong. Lat.	Spot.	Gr. M.T.				
					h	m	
332°50 + 0·560 × Lat.	331°86 − 1°14	Piccolomini	1892 Jan.	4	5	15	Elger.
337·15 + 0·201 „	337·17 + 0·07	Theophilus	93 Apr.	21	8	42·5	Gordon.
338·28 + 0·201 „	338·48 + 1·00	Theophilus	94 May	10	8	15	Mee.
355·13 − 0·258 „	354·79 + 1·34	Manilius	96 Jan.	17	9	30	Elger. Obs. p. 302.
2·48 − 0·304 „	2·62 − 0·46	Plinius	94 Mar.	14	Paris		Knowl. 1895 June.
2·71 + 0·202 „	„ „	Albategnius	„		„	„	1896 April.
3·07 + 0·986 „	„ „	Maurolycus	„		„	„	„
3·17 + 1·200 „	„ „	Cuvier	„		„	„	1895 June.
7·75 + 0·390 „	8·09 + 0·88	Thebit	90 May	24	9	10	Corder.
11·39 + 0·330 „	11·80 + 1·23	Arzachel	88 Sept.	13	16	2	Harvard, vi. 5.
11·51 + 0 233 „	„ „	Alphonsus	„		„	„	vi. 5.
13·39 − 0·409 „	12·77 + 1·53	Conon	89 Oct.	2	15	19	„ vi. 1.
13·58 − 0·529 „	„ „	Archimedes	...		...	„	vi. 1.
16·02 − 0·258 „	15·72 + 1·15	Eratosthenes	91 July	14	...	Lick 1.	
16·19 − 0·415 „	...	Conon	—		—	—	
16·30 − 0·594 „	...	Timocharis	—		—	—	
16·30 − 0·533 „	...	Archimedes	—		—	—	
16·52 − 0·701 „	...	Aristillus	—		—	—	
16·76 − 0·910 „	15·72 + 1·15	Cassini	91 July	14	...	Lick, 1.	
23·33 + 0·350 „	23·77 + 1·24	Arzachel	88 Sept.	14	15	36	Harvard, vi. 6.
23·46 + 0·246 „	„	Alphonsus	„		„	„	„
32·70 − 0·057 „	32·62 + 1·37	Reinhold	89 Sept.	4	18	6	„ v.
32·85 − 0·169 „	„	Copernicus*	„		„	„	„
34·14 − 0·170 „	33·98 + 0·97	Copernicus	91 Oct.	12	(frontispiece)		Lick, 2.
37·65 − 0·429 „	37·30 + 0·81	Euler	96 Mar.	24	9	45	Elger. Obs. p. 440.
49·28 − 0·203 „	49·11 + 0·84	Marius	96 Mar.	25	9	2·5	Elger. Obs. p. 329.
52·03 − 0·432 „	52·53 − 1·15	Aristarchus	94 Nov.	9	8	37·5	Sheldon.
64·41 + 0·093 „	64·49 + 0·90	Damoiseau	87 Dec.	27	8	30	Elger. Obs. p. 399.
103·35 + 1·632 „	105·69 + 1·45	Endymion	89 Sept.	10	18	8	Harvard, vi. 3.
103·80 + 1·329 „	„	Hercules	„		„	„	„
113·09 − 0·463 „	113·67 − 1·25	Petavius	94 Nov.	14	9	30	Sheldon.
113·57 − 0·354 „	113·85 − 0·80	Vendelinus	91 Dec.	17	9	15	Elger.
114·42 + 0·674 „	115·43 + 1·51	Geminus	90 Aug.	31	...	Lick, 3.	
114·66 + 0·515 „	...	Cleomedes	—		—	—	
115·03 + 0·265 „	...	Prom. Agarum	—		—	—	

Sun's Colong. c	s	Sun's Colong.	Lat.	Spot.	Gr. M.T.				
		°	°				h	m	
115·65 − 0·148	,,	...		Langrenus	—		—		—
115·72 − 0·187	,,	...		Goclenius	—		—		—
115·96 − 0·353	,,	...		Vendelinus	—		—		—
116 13 − 0·460	,,	...		Petavius	—		—		—
116·42 − 0·655	,,	115·43 + 1·51		Furnerius	90	Aug. 31	...		Lick, 3.
117·51 − 0·353	,,	117·58 − 0·21		Vendelinus	92	Nov. 6	10	30	Elger.
123·77 + 1·511	,,	123·94 + 0·11		Endymion	88	July 25	21	52	Harvard, vi. 4.
123·82 + 1·102	,,	,,		Hercules		,,	,,		,, ,,
126·87 − 0·035	,,	126 82 − 1·27		Messier	94	Nov. 15	11	30	Mee.
138·53 − 0·569	,,	139·01 − 0·85		Piccolomini	94	Dec. 19	11	0	Elger.
144·39 − 0·552	,,	144·20 + 0·34		Piccolomini	93	Sept. 29*	10	30	Davis.
169·91 − 2·839	,,	172·48 − 0·91		Moretus	95	Oct. 9	Lick	4	Knowl. 1896 Oct.
170·54 − 2·140	,,	...		Scheiner		...	...		,, ,,
170·94 − 1·700	,,	...		Clavius		...	...		,, ,,
171·36 − 1·236	,,	...		Maginus		...	...		,, Oct., Dec.
171·45 − 1·411	,,	...		Wilhelm I.		...	...		,, ,, ,,
171·58 − 0·990	,,	...		Tycho		...	...		,, ,, ,,
171·89 − 0·651	,,	...		Hell		...	...		,, ,,
171·92 − 0·616	,,	172·48 − 0·91		Walter	95	Oct. 9	...		,, ,,
172·66 − 0·983	,,	173·00 − 0·35		Tycho	92	Nov. 10	...		Lick 5.
180·05 − 5·12	,,	184·77 − 0·93		Newton	95	Oct. 9	...		Lick 6.
182·24 − 2·722	,,	...		Moretus		—	—		—
183·84 − 2·083	,,	...		Blancanus		—	—		—
183·03 − 1·886	,,	...		Scheiner		—	—		—
183·30 − 1·588	,,	...		Clavius		—	—		—
183 46 − 1·413	,,	...		Longomontanus		—	—		—
183·66 − 1·192	,,	...		Maginus		—	—		—
183·90 − 0·937	,,	...		Tycho		—	—		—
184·10 − 0·789	,,	...		Capuanus		—	—		—
184·13 − 0·687	,,	...		Cichus		—	—		—
184·19 − 0·626	,,	...		Hell		—	—		—
184·24 − 0·571	,,	184·77 − 0·93		Pitatus	95	Oct. 9	...		Lick 6.
190 19 + 0·167	,,	190·42 + 1·37		Copernicus	91	July 28	...		Lick 7.
217·81 + 0·437	,,	218·48 + 1·50		Aristarchus	89	Sept. 20	0	9	Harvard vi. 2.

* The right date is Sept. 29, not Sept. 3.

In order to ascertain the time when for a spot on the list the Sun is at the same zenith distance as at the time assigned to the photograph or sketch, it is only required to multiply the Sun's selenographical latitude (taken from the ephemeris for the approximate time of the occurrence) by the factor given in the second column of the list, to add the product to the Sun's colongitude (for latiude 0°) in the first column, and to determine, by reference to the ephemeris, the time when the Sun reaches the colongitude thus found. Though the Sun's zenith distance will then be the same as at the time of the photograph or sketch, the effects of the illumination may yet differ sensibly, as they depend also on the Sun's azimuth, and they will therefore only agree if the Sun's latitude is the same on both occasions.

As the daily rate of increase of the Sun's colongitude is between 12°·12 and 12°·25, the ephemeris is sufficiently accurate for finding the time to about a minute. But the time thus found is merely that corresponding to the assigned time of the photograph or sketch, and any error or vagueness of the assigned time is simply reproduced. If the evidence of the sketches is to be used for determining the proper times for measuring the shadows, it is clearly essential that the correct times should be stated when the outlines of the shadows have actually been drawn.

The following are the times of recurrences for a few of the spots in the preceding list, to which is added *Plato* as sketched by M. Elger, 1887 February 1, inserted in the old list of 1891, and also referred to in vol. xlviii. p. 294.

	1897. h m	Feb. h m	Mar. h m	Apr. h m
Piccolomini	Jan. 8 5 30	Feb. 6 20 53	Mar. 8 11 37	Apr. 7 1 13
Theophilus	8 15 12	7 6 0	8 20 10	7 9 24
Manilius	10 3 19	8 17 12	10 6 48	8 19 30
Plinius	10 17 53	9 7 49	10 21 11	9 9 49
Albategnius	10 17 40	9 8 25	10 22 33	9 11 41
Maurolycus	10 17 21	9 9 22	11 0 41	9 14 34
Cuvier	10 17 16	9 9 39	11 1 14	9 15 21
Thebit	11 3 21	9 18 25	11 8 50	9 22 8
Plato	11 13 36	10 2 4	11 14 4	10 1 50
Eratosthenes	11 20 33	10 10 31	11 23 56	10 12 36
Timocharis	11 21 24	10 11 0	12 0 2	10 12 28
Aristillus	11 22 5	10 11 20	12 0 6	10 12 19

	1897.	h m		h m		h m		h m
Piccolomini	May	6 13 28	June	4 22 34	July	...	Aug.	...
Theophilus		6 21 32		5 8 47		...		...
Manilius		8 7 29		6 19 0		6 6 15		4 17 36
Plinius		8 21 48		7 9 19		6 20 38		5 8 5
Albategnius		8 23 45		7 10 58		6 21 40		5 8 20
Maurolycus		9 2 47		7 13 31		6 23 15		5 8 45
Cuvier		9 3 37		7 14 10		6 23 43		5 8 52
Thebit		9 10 13		7 21 18		7 7 46		5 18 10
Plato		9 13 37		8 1 42		7 14 7		6 2 58
Eratosthenes		10 0 33		8 12 2		7 23 18		6 10 42
Timocharis		10 0 22		8 12 0		7 23 34		6 11 21
Aristillus		10 0 13		8 11 58		7 23 48		6 11 52

Col. Cooper's Observatory:
Markree, Collooney, Ireland.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. JANUARY 8, 1897. No. 3

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

William Johnston, Saint Nicholas House, Westgate Street, Gloucester;
George Edward Lumsden, Assistant Secretary of the Province of Ontario, 57 Elm Avenue, Toronto, Canada;
Major Percy Alexander MacMahon, R.E., F.R.S., Artillery College, Woolwich, and 52 Shaftesbury Avenue, W.;
Louis C. H. Maston, San Francisco, California, U.S.A.;
Beauchamp Prideaux Selby, J.P., Pawston, Cornhill-on-Tweed, Northumberland;
J. E. de Villiers, Government Surveyor, Cape Town, South Africa; and
John Watson, Norman Villa, Glossop Road, Sheffield,
were balloted for and duly elected Fellows of the Society.

The following Candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended:—

John Harold Herbert, Civil Engineer, Mapperley Road, Nottingham (proposed by A. A. Common).

Eighty presents were announced as having been received since the last meeting, including, amongst others:—

J. C. Clancey, Aid to land-surveying (two editions); Calculating Tables; Examination questions in surveying, presented by

the Author; Galileo, Opere, Edizione nationale, vol. vi., presented by the Italian Government; *Nautical Almanac* for 1900, and ditto, Part I., presented by the Lords Commissioners of the Admiralty; S. Newcomb, The Mass of *Jupiter* and the Orbit of *Polyhymnia* (American *Nautical Almanac* papers, vol. v. part 5), presented by the American *Nautical Almanac* Office; *Washington Observations*, 1890, Appendix I.; Catalogue of 16,748 southern stars, deduced from observations made by Lieut. Gilliss, presented by the Observatory; Positive and negative reproductions of a photograph of Nebula M 8 *Sagittarii*, presented by K. D. Naegamvala; Photograph of the partial phase of the solar eclipse 1896 August 9, taken at Vadsö, presented by Joseph Lunt.

ALTERATION OF BYE-LAWS.

At the Special General Meeting held after the Ordinary Meeting, the following alteration of Bye-laws was unanimously carried:—

That Bye-laws 69 to 74 be altered by the addition of the word "gold" before the word "medal."

The reasons for, and effect of, this alteration are detailed in *Monthly Notices*, vol. lvii. pp. 35–39.

The Bye-laws in question now stand as follows:—

SECTION XVI.—*Of Awarding the Gold Medal.*

69. No more than one gold medal shall be awarded or given during the course of any one year.

70. At the regular meeting of the Council, in the month of November in every year, the Council shall (prior to any other business) take into their consideration the propriety and expediency of awarding such gold medal; and the name of every person who may be proposed and seconded as deserving the same shall be entered in the Minute-book.

71. Whenever more than one person shall have been proposed, the Council shall, at their regular meeting in December, select one of the persons so proposed to be submitted to the Council in January following on the question whether he shall or shall not receive the gold medal.

72. At the regular meeting of the Council in January following, the Council shall decide whether the nominee then before the Council shall or shall not receive the gold medal.

73. No gold medal shall be awarded in any other way than in the manner and at the time above prescribed; nor unless three-fourths at least of the Members of the Council present shall agree thereto.

74. Notwithstanding the preceding Bye-laws, in cases where two or more persons have been jointly concerned in the produc-

tion of any scientific treatise, or the carrying out of any research, work, or discovery, or have been the simultaneous but independent authors of any such treatise, work, research, or discovery, the Council may, under these circumstances, receive the nomination of such two or more persons as joint recipients of the gold medal, and proceed thereupon in like manner as above mentioned with respect to the names of separate persons; and should the gold medal be ultimately awarded to such joint authors, workers, or discoverers, an impression of the gold medal shall be provided for, and given to each of such joint recipients.

The Total Solar Eclipse of 1896, *August* 9. *Reports of Observers communicated to the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society.*

The following Reports have been received, and communicated by the Committee to the Royal Astronomical Society for publication. Mr. Stone's report on observations made in Novaya Zemlya will be published in the *Memoirs*.

Report on the Expedition to Japan to observe the Total Solar Eclipse of 1896, *August* 9.

By W. H. M. Christie, M.A., F.R.S., Capt. E. H. Hills, R.E., and H. H. Turner, M.A., B.Sc.

1. Thick clouds obscured the Sun at the time of Total Eclipse, and no photographs were taken or observations made. But the following notes on the Expedition may be interesting to other observers:—

2. This Expedition was organised by the Joint Permanent Eclipse Committee of the Royal Society and Royal Astronomical Society, funds being provided from a grant made by the Government Grant Committee. The observers are indebted to the Canadian Pacific Railway Company and the Allan Line for a considerable reduction of fares, and for the free carriage of their instruments from Liverpool to Yokohama and back to Montreal. By the kindness of the Lords Commissioners of the Admiralty the Expedition was assisted in Japan by several of Her Majesty's ships of war, as mentioned in detail in the next paragraph.

3. *Personal.* — The following persons took part in the Expedition:—

W. H. M. Christie, M.A., F.R.S., Astronomer Royal.
H. H. Turner, M.A., B.Sc., Sec. R.A.S., Savilian Professor of Astronomy at Oxford.
Captain E. H. Hills, R.E., Instructor in Chemistry and Photography at the School of Military Engineering, Chatham.

In what follows these are usually designated by the initials C., T., H. respectively.

It was originally proposed that Captain W. de W. Abney, C.B., F.R.S., should also take part in the Expedition, in which case the observers would have divided into two pairs, and occupied two stations. But Captain Abney ultimately found it impossible to go to Japan, and the number of observers was thus reduced to three. The Astronomer Royal could not reach Yokohama before July 27, owing to the necessity for his presence at Greenwich on Visitation Day (June 6), but the greater part of his equipment was taken out and set up by the other observers, who left three weeks earlier. Under these circumstances it was not found practicable to occupy two stations, and no attempt was made to do so. Even with this simplified programme, the whole of the time available for preparation was fully employed, and the observers feel that the restriction was justified by their experience.

4. *Itinerary.*—The observers T. and H. left Liverpool in R.M.S. *Sardinian* (Allan Line) on May 28, arriving at Montreal on June 8.

They reached Vancouver on June 21 ; embarked on R.M.S. *Empress of Japan* the following day, and arrived at Yokohama on July 5. They found H.M.S. *Humber* waiting to convey them to the selected station in the island of Yezo. A few days were spent in some official visits and in discussing the most suitable stations, and the observers embarked on the *Humber* on July 13, arriving at Akkeshi on July 16. In the bay five of H.M. ships were already anchored, under the command of Vice-Admiral Sir Alexander Buller, on the flag-ship *Centurion* ; and the observers have to gratefully record the generous assistance given them by the Admiral and the officers of the fleet. Three ships in all rendered special aid to the Expedition, viz., H.M.S. *Humber*, which conveyed the observers T. and H. to Akkeshi ; H.M.S. *Linnet*, which conveyed the Astronomer Royal thither from Yokohama, and the officers and men of which assisted the observers in their programme for totality ; and H.M.S. *Pique*, which conveyed the whole party back to Yokohama. It may be mentioned that the chief reason for this division of labour was the breaking down of the Japanese railway from Yokohama to Aomori. The Astronomer Royal had proposed to travel by rail to Aomori in order to save time, and the *Humber* was to meet him there, but the above-mentioned break-down necessitated a change of plans, and fortunately the *Linnet* was able to bring him direct from Yokohama, remaining with the observers till after the eclipse. For conveying all the observers back again, the Admiral sent up the *Pique*. It will be seen how much the Expedition owes to the readiness with which Admiral Buller met an unforeseen contingency.

The Astronomer Royal left Liverpool in R.M.S. *Laurentian*, on June 18, arriving at Montreal on June 29. After some delay,

through floods in the Rocky Mountains, he reached Vancouver on July 12, and sailed in R.M.S. *Empress of China* on July 13, arriving at Yokohama on July 26 ; left Yokohama in H.M.S. *Linnet* on July 29, arriving at Akkeshi on the morning of August 1, and was landed at once.

It may be added that the day after the arrival of the observers T. and H. at Akkeshi was spent in exploring the neighbourhood and selecting a site for the station. An American party, with Professor Schaeberle at the head, and a Japanese party under Professor Shin Hirayama, of Tokio Observatory, were already established. After consultation with them, and inspection of the neighbourhood, the observers had little difficulty in choosing a site, and arranged to land their instruments in a "sampan" (or Japanese flat-bottomed boat, which could be run up on the beach) the next morning. But owing to dense fog the "sampan" failed to find the *Humber*, and put back to shore after a four hours' search. On the morning of July 19, however, all the apparatus was safely landed, and work was commenced at once.

5. *Selection of a Station.*—There were three sets of stations available:

(*a*) Stations on the north-east coast: Soya, Esashi (Yessassi), Mombets, &c.
(*b*) Stations inland: Shibetcha, &c.
(*c*) Stations on the south coast: Kushiro, Akkeshi, Hamanaka.

(*a*) Were perhaps best as regards weather (see below), but were condemned by the Hydrographer as regards anchorages, which are bad. The ship could not with any certainty have remained with the observers.

(*b*) Meteorological observations showed that Shibetcha was very bad. An opinion was expressed by Dr. Knipping, of Hamburg, and communicated to us by Professor D. P. Todd, that if an observer could get inland from Kushiro to the lee side of the Sulphur Mountains he would have perhaps the best chance of weather. But this would have been a considerable undertaking, requiring much time, and was not attempted. With regard to other inland stations, it may be remarked that the island of Yezo is thickly wooded inland.

(*c*) Kushiro was originally selected as the headquarters of the Expedition, on the advice of Professor Milne, F.R.S., who knew the district. But just as the observers T. and H. were leaving England, information was received from the Japanese Hydrographic Office, recommending the north-east coast (stations *a*) rather than the south coast (stations *c*), on the ground that the prevailing winds, being southerly, blew up fog to the latter stations. At the same time our own Hydrographer condemned the anchorage at Kushiro, and suggested Akkeshi or Hamanaka instead. On arriving at Yokohama the observers had thus to

face the question whether to proceed to Akkeshi or to attempt an entire change of programme by going to some place on the north-east coast, in accordance with the suggestions of the Japanese Hydrographic Office.

The observers have here to acknowledge the valuable help accorded them by the British Minister, Sir Ernest Satow, who was able to obtain for them just the information they required. He first put into their hands a pamphlet by Professor Nakamura, Director of the Central Meteorological Observatory in Tokio, wherein meteorological observations at different stations in Yezo were tabulated and discussed; and secondly, found for them a Japanese who knew the island of Yezo well, was an excellent navigator, and could speak very good English. From both sources of information it appeared that Akkeshi was equal, if not superior, to the north coast. Further, there were already three strong parties on the north-east coast (Professor D. P. Todd, M. Deslandres, Professor Terao), so that observations there would be well provided for. The decision was accordingly taken to proceed to Akkeshi (spelt Akishi on the Admiralty Chart).

A brief extract from Professor Nakamura's pamphlet is here appended :—

"The undermentioned table shows a cloud condition near the Sun's disc, which has been found from the average of the tri-daily observations (2 P.M., 2.30 P.M., and 3 P.M.) extending over three years, 1893–1895, from July 25 to August 25. Cloud conditions are denoted by five symbols :—

0 means entirely free from clouds.
1 „ generally scattered.
2 „ clouds massed about the Sun.
3 „ the Sun in fog or haze.
4 „ the Sun invisible in thick clouds.

The number of observations, in percentage, distributed under each symbol, is given in the following table :—

	0			1			2			3			4		
Name	2.0	2.30	3.0	2.0	2.30	3.0	2.0	2.30	3.0	2.0	2.30	3.0	2.0	2.30	3.0
Soya	27	25	25	21	24	21	10	11	8	5	5	5	36	34	40
Esashi	56	56	56	12	12	12	6	6	6	4	4	4	21	21	21
Mompetsu	58	57	55	9	7	8	5	6	5	1	2	2	23	23	26
Abashiri	30	27	26	10	12	13	5	6	6	0	0	0	54	54	54
Nemuro	23	20	20	17	17	16	10	11	13	9	11	11	40	40	39
Akkeshi	40	41	41	31	28	27	2	1	2	8	9	9	18	18	18
Shibetcha	20	17	17	8	12	11	26	26	24	0	0	0	46	48	48

If we regard cloud conditions which are denoted by 0 and 1 to be suitable for observation and the others unsuitable, then the percentage at the observation hour becomes as follows :—

	2.0 P.M.		2.30 P.M.		3.0 P.M.	
	Favourable.	Unfavourable.	Favourable.	Unfavourable.	Favourable.	Unfavourable.
Soya	48	52	49	50	46	53
Mompetsu	69	30	67	33	66	34
Esashi	68	31	68	31	68	31
Abashiri	40	59	39	60	39	60
Nemuro	40	59	37	63	36	63
Akkeshi	71	28	72	28	71	29
Shibetcha	28	72	29	71	28	72

Below is given the record of weather at the time of totality at Akkeshi during the stay of the observers :—

July 19	Cloudy.	July 27	Fine.	Aug. 4	Fine.
20	Cloudy.	28	Cloudy.	5	Fine.
21	Cloudy.	29	Cloudy.	6	Cloudy.
22	Very fine.	30	Fine.	7	Cloudy.
23	Fine.	31	Doubtful.	8	Very fine.
24	Doubtful.	Aug. 1	Cloudy.	9	Cloudy.
25	Cloudy.	2	Cloudy.	10	Very fine.
26	Fine.	3	Raining.	11	Fine.

On arrival in Akkeshi Bay it was not difficult to make a choice of station, aided by the experience of Professor Schaeberle, who had already been ashore eleven days. He had remarked that the sea-fog (which was only too prevalent throughout our stay) lay about the hills and inland when it was clear in the little basin in which the village lay. We accordingly put up at a tea-house, or inn, in the village, and erected our huts in the yard at the back within a ring-fence, which kept out not only inquisitive human beings, but dogs and poultry. The Governor of the place and the Chief of Police at once took us under their protection, and we were never interfered with in any way, but on the contrary received every kindness. We had never any reason to regret our choice on the score of weather. We often had it beautifully fine when there was dense fog at sea. For instance, on the day before the Eclipse, the Sun shone uninterruptedly from a clear blue sky, while Admiral Buller, who had come up in H.M.S. *Alacrity* to see the Eclipse, was kept outside the bay in a dense fog only a few miles away, and did not venture to come in till the Monday morning after the Eclipse. On the actual day of the Eclipse we could not have been better situated in the neighbourhood, for the fog and cloud did lift to us occasionally, though it remained dense elsewhere.

6. *Instrumental Equipment.—The Astronomer Royal.*—The "Thompson" photoheliograph : O.G. 9 inches aperture and

8 ft. 6 in. focal length, with secondary magnifier placed a short distance within the focus, giving an image of the Sun 4 inches in diameter. The telescope was pointed to a 16-inch plane mirror made by Dr. Common, and mounted as a cœlostat by Mr. Hammersley after design by Dr. Common; the Sun's rays being thus reflected into the telescope. The camera was furnished with eight plate-holders, taking 12 × 10-inch plates.

Professor Turner.—The double camera used in the Fundium Expedition of 1893 by Sergeant Kearney. The tube is of wood, 6 feet long and 14 × 7 inches in section, divided by a partition into two square tubes of 7 × 7-inch section. In one of these is placed the "Abney"* lens of 4 inches aperture and 5 feet 2 inches focal length, giving an image of the Sun 0·57 inch in diameter; in the other the photoheliograph objective No. 2 (used in transit of *Venus* expeditions), of 4-inch aperture and 5 feet focal length, with a Dallmeyer secondary magnifier of 7½ inches focus placed 5 inches within the focus, and giving an image of the Sun 1½ inch in diameter. The camera furnished with six plate-holders, each taking two plates of 160 × 160 mm., as in use for the astrographic chart; both plates being exposed by a quarter turn of one shutter. The camera pointed to a 16-inch cœlostat as above.

On the tube was mounted a polariscopic apparatus consisting of an ordinary slit spectroscope (and telescope), with an Iceland spar double image prism substituted for the ordinary prisms. Further explanation of this apparatus is given below.

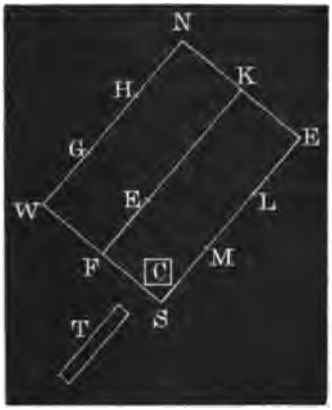
Captain Hills.—Two slit spectroscopes:

	No. 1.	No. 2.
Objective	Cooke achromatic 4½ inch aperture, 5 feet 10 inch focus.	Single quartz lens 5 inch aperture, 4 feet 9 inch focus.
Collimator and Camera lenses	Single quartz lens 2½ inch aperture, 30 inch focus.	Single quartz lens 3 inch aperture, 36 inch focus.
Slit	1½ inch × 0·004 inch.	2 inch × 0·004 inch.
Prisms	Two flint prisms of 60° 4⅓ inch base, 2½ inch height.	Four quartz prisms of 60° 3¼ inch base, 2¾ inch height.
Prisms at min. dev. for	Hγ.	Hε.
Position of slit	Tangential to Sun's limb at point of second contact.	Diametral.

* One half of a doublet photographic lens by Dallmeyer belonging to Captain Abney used in the Eclipse Expeditions of 1886, 1887, 1889, 1893, and 1896: acquired from him by the Royal Astronomical Society in 1893 for permanent use in Eclipse expeditions, in consideration of their replacement by two others.

7. *Huts.*—The huts for the instruments were made of wooden frames covered with Willesden waterproof canvas. These were made before starting, and taken out with the instruments. The canvas was brought away after the eclipse, and the wood left behind. This procedure is recommended for future expeditions.

The huts for observers C. and T. were arranged on the plan suggested in *Monthly Notices*, vol. lvi. p. 410. The corners were placed N., E., S., and W., and the cœlostats (C.) mounted on foundations of gravel and Portland cement in the south corner. Two sliding doors, MS and FS, met at the south corner, admitting the Sun to the cœlostat in the morning and afternoon respectively. The telescopes (T.) were placed in the azimuth indicated in the diagram. The distances SF, FW, WG, GH,



HN, &c., were all about 4 feet, slightly less than the width of canvas. There was a ridge roof, with ridge along the line KF; and T.'s hut was completely partitioned along FK to form the dark-room in the portion WNKF, a lining of brown paper being used to form the dark-room. The paper used was such as is put under carpets, with a pattern of depressions in it to make it soft to the feet; but these depressions or bulges were found to be easily pierced, and thus let in light; ordinary brown paper would have been better.

The arrangement was found to work well on the whole.

H. adopted a different plan. His heliostat and object-glasses were placed outside the main hut on a concrete foundation, and were protected by a small structure of the same wood and canvas, which could readily be thrown off. Inside the main hut was placed a firm table on which the spectroscopes were mounted. The tubes to connect the object-glasses with the spectroscopes were made of black paper on wooden laths on the morning of the Eclipse. This arrangement also was found to work well.

8. *Mounting and adjustment of Cœlostats and Heliostat.*—The places for the huts having been marked out on the

ground, the cement bases were made at once, so that they might have time to set while the huts were being put up. Rectangular wooden frames were made, sunk an inch or two into the ground (which was tolerably hard), and filled with shingle and Portland cement. A layer of sand and cement was placed on the top to give a good surface. Before the cement was quite hard the heavy metal bases for the cœlostats were placed in position roughly, so that they might bed into the cement.

The adjustment of the axes of the cœlostats was effected very quickly by means of the attached declination theodolites. The level attached to the telescope makes it possible to adjust in altitude without any astronomical observation, for the latitude of the place can be taken from the chart with sufficient accuracy; and setting the telescope to the south declination equal to the co-latitude, and in the meridian, the level should indicate horizontality. Index errors of the circle and level are eliminated by reversal of the instrument. There is a slight uncertainty attending the placing of the telescope in the meridian, but this does not seriously affect the adjustment in altitude. If a cross-level were made for the pivots of the telescope this uncertainty could be removed.

To adjust in azimuth we must have an observation of the Sun (or a star) at a distance from the meridian. Observing his declination (in reversed positions of the instrument and taking the mean), the instrument must be moved in azimuth until this observed declination agrees with that given in the *Nautical Almanac*. A very few trials, if the Sun can be seen for half-an-hour, will soon indicate the true azimuth without any calculations, within a minute or two of arc, though if the instrument is moved much the altitude observation should be repeated.

After the initial adjustment of the cœlostats they were not disturbed, but observations were repeated at intervals with the following results. The individual readings were only taken to minutes of arc, but both limbs of the Sun were observed in both positions of the instrument, and the mean of the four set down.

C.'s instrument: Observer T.

Date.	(G.M.T.)	Hour angle of Sun.	Observed Decl.	Tabular Decl.	O−C.
	h	h	° ′	° ′	′
July 20	19·7	+5·0	20 23·0	20 22·7	+0·3
21	9·7	−5·0	20 14·3	20 15·6	−1·3
21	17·5	+3·2	20 10·5	20 11·8	−1·3
22	12·0	−4·3	19 59·8	20 2·3	−2·5
25	17·7	+3·4	19 18·5	19 20·4	−1·9
25	19·0	+4·7	19 18·8	19 19·7	−0·9
25	19·5	+5·2	19 19·8	19 19·4	+0·4
26	10·7	−3·6	19 9·0	19 11·0	−2·0
29	11·5	−2·8	18 25·5	18 28·2	−2·7
29	18·8	+4·5	18 24·0	18 23·8	+0·2
31	11·3	−3·0	17 57·8	17 58·7	−0·9

From this general watch kept on the instrument, it seemed clear that the adjustment remained good within 2′ or 3′, which is sufficient for the purpose. The error was chiefly in altitude, and by an unfortunate oversight, observations with the level for altitude were not recorded, though one or two were made, and the history of this small displacement cannot be traced. But observations made by C. after his arrival gave the following results :—

Date.	(G.M.T.)	Hour angle of Sun.	Observed Decl.	Tabular Decl.	O−C.
	h	h	° ′	° ′	′
Aug. 7	19·3	5·0	16 0·7	15 59·7	+1·0
7	19·3	observation with level			−2·7

T.'s Cœlostat : Observer T.

This instrument was used with the driving-rod and gear at the upper end of the axis, which brings the theodolite to the lower end. The adjustments were made before mounting the mirror in the working position, and could not well be tested afterwards without reversing the mirror. Hence we have no information between July 22 and August 3, when a displacement in altitude was found as in the case of C.'s instrument.

Date.	(G.M.T.)	Hour angle of Sun.	Observed Decl.	Tabular Decl.	O−C.
	h	h	° ′	° ′	′
July 21	18·3	+4·0	20 14·0	20 11·4	+2·6
22	10·3	−4·0	20 4·8	20 3·2	+1·6
Aug. 3	12·0	−4·3	17 17·0	17 11·3	+5·7
3	12·0	observation with level			+8·5
3	17·0	+2·7	17 13·8	17 8·0	+5·8
		Instrument adjusted in altitude.			
3	17·5	observation with level			+1·0
3	18·0	+3·7	17 7·8	17 7·3	+0·5
7	15·0	+0·7	16 8·8	16 2·8	
7	15·0	observation with level			+2·0

H.'s Heliostat : Observer T.

This instrument not having any special means of adjustment provided, the following plan was used to adjust the polar axis.

A wooden cap was made for the end of the polar axis on which one of the cœlostat theodolites could be fitted, and the whole was bound up firmly with string, as the best method of mounting the theodolite on this axis at command. The adjustment was thus conducted as for the cœlostat. The nature of the mounting gave a little extra trouble, but when some few difficulties had been overcome the adjustment was successfully carried out. It is not so important for spectroscopic observations that the adjustment should be perfect, and the labour of re-testing at a later date was omitted.

9. *The Driving Clocks.*—The clocks for the two cœlostats seem unnecessarily heavy in construction, considering the small amount of work to be done, but it does not seem impossible that they may be made to work well. As a matter of fact, T.'s clock gave a good deal of trouble, though the mechanism was not directly to blame. On July 31, after having performed very well day after day, it suddenly stopped, and could not be made to go, even with much extra weight. It was taken to pieces by T. and carefully cleaned, and went well for one day, when it stopped again. A scrutiny revealed the fact that the great weight required to drive the clock had gradually strained the wooden support so that the weight-cord was now rubbing tightly against the side of the opening from the clock-case, producing great friction. The clock was moved about two inches forward and the support strengthened, and all went well for another day, two weights being now sufficient for driving instead of four. Then came another stoppage, and five weights would not drive it. It was again taken to pieces and thoroughly examined by T. and H., when it was found that the upper pivot of the governor would jam unless the plate in which it worked was pressed tightly to one side before screwing it down. When this was done the clock ran easily, and continued to do so until the day of the Eclipse. The primary cause of the series of difficulties was almost certainly the great weight required to drive the clock, which strained the support in the first instance.

The cœlostat clocks, when in good order, kept a fair rate. The governor makes a slight noise twice every second, by which the rough adjustment of rate can be made. For fine adjustment a mark was placed on one of the wheels, which revolves four times a minute, and transits of this mark were observed at intervals ; or the image of the Sun was received on the ground glass of the telescope by reflection from the cœlostat, and its steadiness observed. The two methods were found to agree satisfactorily, showing that the radius of the driving sector is of the right length or rather that the teeth are properly cut. The clock stops when winding, which is an inconvenience. For instance, on the actual day of eclipse the Sun appeared about half an hour before totality, and the image was adjusted on the ground-glass. It was important not to lose it again, and so the clock was kept running ; but having to be wound up some minutes before totality, the image was displaced by the stoppage of the clock. The time lost was, however, only a few seconds, and the displacement not serious. It might even have been corrected if necessary in the following way : before winding, the mark on the wheel was transiting at 6^s, 21^s, 36^s, and 51^s in each minute ; after winding, at 13^s, 28^s, 43^s, and 58^s. The rate of the clock might have been increased (by a gentle twist on the driving rod) until the transits again occurred at 6^s, 21^s, 36^s, and 51^s. Or the ordinary slow motion might have been used if its relation to the clock rate was known ; it could not of course be used in the ordinary way so long as the Sun was not visible.

10. *Focussing of Telescopes.*—One of the uncertainties that harass the eclipse-observer is his ignorance of the amount of fine weather he will have before the eclipse for adjusting. He must have some astronomical observations to set up his equatorial in position, and he has been accustomed to depend upon star photographs for his focussing. But the experience of the present Eclipse, and especially the introduction of the cœlostat into eclipse work, has done something towards making him independent of weather. The adjustments for position have been simplified by the introduction of the attached level, and experience has shown that the instrumental azimuth will remain steady, so that one glimpse of the Sun or a known star is sufficient to set up the instrument, and it has been found that the focus can be very conveniently and accurately obtained with the help of the plane mirror and without any astronomical observations at all. It is not the first time that methods of focussing by terrestrial means have been proposed or tried. Dr. Schuster proposed in 1886 (*Phil. Trans.* vol. 180 (1889), Ap. 302) to focus on a terrestrial object at a moderate distance. With a properly constructed tube it should be possible to do the focussing before leaving England, though the experience of this Expedition shows that it is advisable to confirm it on arrival at the station. There should in future be no difficulty about doing this in the manner described below, and the writers of this report feel that the introduction of the cœlostat into eclipse photography has simplified the problem very sensibly.

The method was briefly as follows: Pointing the telescope normally to the mirror, the image of a bright point in the focal plane will be formed in the focal plane. If the bright point be outside the focal plane its image will be within, and *vice versâ*. Now prepare a special spare back for one of the plate-holders with holes in it, through which the light of a candle may be admitted. To form a definite image, wire gauze should be placed in the holes, or some other device used, and the holes should be confined to one-half of the back. Cutting a plate in two, place one-half in the plate-holder where the back is not perforated; then when light is admitted through the holes, a reflected image will be photographed on the half-plate.

Wire gauze placed in the plane of the film was used to form the image by C. Two different devices were used by T. In the first a slip of glass, 3 inches long by $\frac{1}{2}$ inch wide, coated with black varnish, and then ruled with five lines, was held firmly by the back of the plate-holder in a plane *inclined* to that of the film, one end being in the plane of the film and the other about an inch from it. Only one point of any of the ruled lines could thus give a good image at the same exposure, but from the position of this point it could be inferred how much further the object-glass must be moved. In the second method the half of an old plate was coated with black varnish, ruled with lines, and placed in the unoccupied half of the plate-holder. It was

thus made quite certain that the origin of light was in the plane of the film. Other devices will probably occur to others.

If the image is not in focus, the object-glass (or the secondary magnifier) must be moved until it is, for in the tubes used in this Expedition the plate-holder came against a fixed bearing. It was found possible to focus with considerable accuracy, a displacement of 0·01 inch in the secondary magnifier making a sensible difference. To move the magnifier through such small distances, C. used thicknesses of paper cut in the shape of collars, and placed between two flanges arranged for the purpose, one on the tube holding the magnifier, and the other on the tube into which it slid. T. unscrewed the object-glass through a fraction of a turn, having no flanges available.

The following are the details of the observations for focus :—

(*a*) *The Thompson Photoheliograph.* Observer C.—Focussing of Thompson photoheliograph, 1896 August 4. Tried focus as found at Greenwich, with ring on concave magnifier marked right focus, using method by reflection from mirror, the telescope being in east direction nearly horizontal. Found focus required alteration ; put in two rings of zinc and two of paper, and took another photograph. Lens required to be moved out farther. Four photographs for focus were then taken on this and following days :—

(1) Four thicknesses of note paper added to the two of zinc and paper. August 4.

(2) Two thicknesses of cartridge paper added. August 7. Focus very nearly right.

(3) Two thicknesses of brown paper added. August 7. Focus much worse than No. 1.

(4) *One* thickness of cartridge paper added to No. 1. *i.e.* the two thicknesses of brown paper and one thickness of cartridge paper removed. This gave the best focus, better than No. 1, and was adopted August 8.

N.B.—The object photographed was the hole with net over it, just above the centre of the field, and the reflected images were in a line a little below the centre. A cross is scratched in right-hand lower corner, as placed in telescope.—W. H. M. C.

(*b*) *The Abney Lens.* Observer T.—D = distance of rim of cell of object-glass from end of wooden tube in inches. The film was 6 feet $\frac{1}{16}$ inch from the same end of tube by measurements such as can be made with a 2-foot rule.

On August 3 three exposures were made with the inclined slit : D = 10·60 inches, 10·80 inches, 11·00 inches.

Calling the end of the slit which is in the plane of the film

E, and a point distant 1 inch from E in the plane of the slit E + 1, then when

D = 10·60, E was in fair focus.

D = 10·80, E + 1·3 was in fair focus.

D = 11·00, E + 2·0 was in fair focus.

Now the inclination of the slit was 1 in 3; hence E + 1·3 was 0·43 inch distant from the film, and the plate or object-glass should be moved through half this amount to get good focus. Hence the values of D indicated by the three exposures are—

(1) . . . . . 10·60 − 0·0/6 = 10·60

(2) . . . . . 10·80 − 1·3/6 = 10·58

(3) . . . . . 11·00 − 2·0/6 = 10·67

D was set as accurately as possible at 10·65, by pushing or pulling the sliding tube, which fitted rather tightly. But as the first exposure above seemed to indicate a smaller value for D than this, and as star-trails taken on August 4 at this reading, though very good, seemed possibly capable of improvement, another plate was exposed on August 8 in three positions of the O.G., determined by unscrewing it slightly, the first having it hard up, the second unscrewed an eighth turn, the third a quarter turn. For this plate the inclined slit was removed and a half-plate blackened, and then scratched, placed in the carrier as described above. The individual images were thus: the first and second were equally good, and the third distinctly worse. Accordingly the O.G. was unscrewed $\frac{1}{16}$ turn as the adopted position for the Eclipse.

(25 turns = 1 inch.)

(*c*) *The Dallmeyer Lens.* Observer T.—(First plate). The object-glass was unscrewed through fractions of a turn (12 turns to the inch, 1 turn = 0·08 inch), from a position in which its rim was 1″·90 from the end of the tube, the rim of the magnifier being 14″·50 from the *other* end.

1st exposure O.G. hard up.

2nd exposure O.G. unscrewed $\frac{1}{8}$ turn = 0·04 inch.

3rd exposure O.G. unscrewed 1 turn = 0·08 inch.

By some accident the first was not on the plate. The second and third were both fair, the second rather better. Another plate was exposed for confirmation, and all three images were on the plate, second and third being about equal, first distinctly worse. Thus a position of the O.G. about 0·06 inch or 0·05 inch further from the enlarging lens was indicated. There is no slide tube for the O.G., and as it was not considered advisable to unscrew it so much as this, the magnifier was moved $\frac{1}{16}$ inch nearer the plate by its slide tube, and clamped up tight. In this position satisfactory star-trails were obtained in the evening of August 4. But for final confirmation another plate was exposed by candle-

light on August 8 with O.G. home, unscrewed $\frac{1}{8}$ turn and $\frac{1}{4}$ turn. The third was distinctly worse than the other two, and the first slightly better than the second. Hence the O.G. was screwed home for the Eclipse.

It may be noticed that no mention has been made of the inclined slit in connection with the Dallmeyer lens, though it was used for the earlier photographs. The fact is its graduation is not so effective when there is an enlarging lens. The distance that must be accurately adjusted is that between O.G. and magnifier, and a slight change in the distance of the plate from the combination does not matter very much. The displacement of the plate is in fact m^2 times the corresponding displacement of the magnifier, where m is the magnifying power.

The above measurements, being made with a foot-rule, do not claim any great accuracy, but they should be sufficient to give anyone who uses the tube in the future an approximate focus on which he may refine.

Several plates not mentioned above were more or less failures, such as are common in trying a new method, however simple.

Besides the star-trails on August 4, with both instruments, two plates with six exposures each were taken of the Moon on July 30 : O.G. rim 1·90 inch from end of tube, as above, and the rim of the magnifier 14 and x/16 inches from the other end, where x had the values :

	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)
1st plate	8	10	12	8	6	2
2nd plate	8	7	6	9	10	(cloudy)

In the first plate (*d*) and (*e*) were fair.

In the second plate (*b*) was the best, agreeing with the reading subsequently found by reflection from the mirror. Such confirmation of the focus by astronomical exposures is eminently desirable when possible, but it is comforting to be able to dispense with it ; for in many climates there is a heavy dew at night, which is anything but good for the instruments, as was the case on the present occasion at Akkeshi.

11. *Programme of Observations.*—C.'s eight slides were filled, and intended to be exposed as below :—

No. of Slide.	Exposure. s	Plate.	Developer to be Used.
1	1	Ilford ordinary	Pyro-soda.
2	5	Ilford rapid	Pyro-soda.
3	5	Ilford ordinary	Pyro-soda.
4	10	Rocket (backed)	Amidol.
5	2	Ilford ordinary	Amidol.
6	20	Rocket (backed)	Eikonogen.
7	10	Ilford ordinary	Pyro-soda.
8	1	Ilford ordinary	Eikonogen.

T.'s six slides were filled as below, the same plates being used for the Dallmeyer and Abney lenses in each case, and standard squares being impressed on plates 1, 2, and 5 :—

No. of Slide.	Exposure. s	Plate.	Developer to be Used.
1	1	Ilford ordinary	Pyro-soda.
2	2	Ilford rapid	Eikonogen.
3	20	Rocket (backed)	Eikonogen.
4	5	Mawson and Swan (backed)	Amidol.
5	2	Ilford ordinary	Pyro-soda.
6	1	Photo mechanical	Amidol.

H.'s four slides were filled as below :—

Spectroscope.	No. of Slide.	Exposure.	Plate.
No. 1	1	Twelve of 1ˢ	Lumiere green sensitive orthochromatic.
No. 1	2	Two of 80ˢ and 30ˢ	
No. 1	3	Twelve of 1ˢ	
No. 2	4	Two of 80ˢ and 30ˢ	Imperial flash-light.

Slides 1 and 3 were to be exposed during the 20 seconds, commencing about the 15th preceding totality, and the corresponding period at the end of totality.

For slides 1 and 2 the slit was tangential at the point of second contact ; for slide 3 the slit was tangential at the point of third contact ; for slide 4 the slit was diametral.

12. *The Polariscopic Observations.*—(This paragraph by T.) In the spring of 1894 I made some measures on the photographs of the corona in 1893 with Captain Abney's revolving-sector photometer. A sufficient number of measures was made to determine the general diminution of coronal light with distance from the Sun's limb, but the time at disposal did not allow me to complete the investigation by taking some particular streamer and exploring its detail. In hopes of doing this in the near future, I did not publish the results as far as they went, though a brief account of them was given to the British Association at the Oxford meeting of the same year (B.A. Report, 1894, p. 568).

Meanwhile the simplicity and beauty of this photometric method had so much impressed me that the extension of it to other cases naturally presented itself, and, in particular, it occurred to me that if a photograph of the corona could be taken with polarised light, and the density of deposit measured at different points, we should obtain a very much more complete knowledge of the extent to which the coronal light is polarised than we have at present. In 1878 some small photographs of the corona were obtained, the light being polarised in planes at right angles (*Washington Observations*, 1876, Appendix III., plate 29), but

no attempt at measuring them was made, and the method of obtaining them was rather rough.

In considering the best form of apparatus, I first thought of placing an achromatised double-image prism of Iceland spar in front of the object-glass of a small telescope. This would give two images of the corona polarised in perpendicular planes, but each impressed on the sky belonging to the other as background. If a large separation of the images could be obtained, the interference of the sky belonging to the other image might be nearly uniform, and not very great; but this would mean a great expense, at the present price of Iceland spar. On thinking over the matter further, however, a different method suggested itself. The above arrangement is analogous to the spectroscope with objective prism, which gives a series of coloured images, each impressed on the sky of the others. With the double-image prism there are only two instead of a number, but this difficulty of confusion is common to both instruments. But the colours of the spectrum can be separated from each other, and this confusion avoided, by the use of a different instrument—namely, the spectroscope of ordinary form, telescope, collimator with slit, prism, camera.

If colour is regarded as continuous, only an infinitely small slit will give a pure spectrum. But if any finite number of colours is assigned, there will be a definite width of slit for which each colour is completely separated from the rest. With half the number of colours, the slit may be just twice as wide; if we again halve the adopted number of colours, we again double the width of slit, and so on. If we have only two colours, the slit may be a considerable width, and yet the images in the two colours be completely separated. Now the Iceland-spar prism is practically a direct-vision prism giving only two colours—the two kinds of polarised light. We have then only to replace the prism of a direct-vision photographic spectroscope by our achromatised Iceland-spar prism, and we have an apparatus giving us two images of the corona (or part of it) in polarised lights without interference.

Such an instrument was arranged for the recent Eclipse, but as no results were obtained, it seems unprofitable to describe it in detail here. This brief sketch of the method will probably be sufficient to guide anyone who wishes to try it, and to whom it had not already occurred. Two remarks may be added:

(1) The focus is not quite the same for the two images. It seems advisable to receive them on separate plates, the focus of each being adjusted independently, though some other way of getting over the difficulty may suggest itself.

(2) The angular separation of the images depends on the focal lengths of the lenses employed as well as on the prism. It is easy either to work it out theoretically, or to observe it experimentally, and then adjust the slit so that there is no overlap. The slit of an ordinary spectroscope may be employed if it will open wide enough, but a rougher slit of metal (or even paper if it be remembered not to use it on the uneclipsed Sun) may be used.

13. *Assistance.*—C. and T. each required four assistants: viz., one to expose at the object-glass end, one to record time of exposures, and two to hand and receive the plate-holders in order. The officers of the *Linnet* who assisted were :—

Recorder for C., Lieut. S. M. Agnew
Exposer for C., Lieut. H. A. Gillett.
Recorder for T., Mr. H. O. Jones.
Exposer for T., Mr. R. B. Garde.

At 15^s before totality (estimated by the previously calculated length of the diminishing crescent) T. was to give the signal "Stand by," in order that H. might make spectroscopic exposures near second contact. At totality he was to call sharply, and two signalmen, A and B, with a stop watch and chronometer, were then to count time as follows: A to record the time of the signal by the chronometer, B to start the stop watch and count from it, "One, two, three, &c." up to sixty seconds, in a loud voice; the next minute was to be similarly counted by A, the change of voice reminding the observers of the change of minute, and the 35^s or 36^s of the third minute by B again, A recording the signal given at the end of totality. The exposer exposed at a signal given to him by the observer when the plate was in position, the beginning and end of exposure being noted by the recorder. In the case of the longer exposures the recorder reminded the exposer quietly at what count he was to close up.

H. only required two assistants: an officer to make the exposures with spectroscope 2 (Lieut. Stevenson, R.N.), and a sailor to hand slides.

All these operations were rehearsed several days before the eclipse, viz. on—

August 5, four times, without plates.
August 6, five times, „ „
August 7, three times, „ „
August 8, once with all slides filled, once again without plates.

On August 7 and 8 all the rehearsals passed off without any hitch.

The Day of the Eclipse.—Quite cloudy and foggy in the morning. All was ready and in good order. The Sun appeared at noon through cloud, and was visible at intervals. The partial phases of the Eclipse were seen until about twenty minutes before totality, when the clouds closed in completely. The counting of seconds was begun some ten seconds after totality had commenced, as judged by the darkness; the commencement was not very well marked, but the observers all agreed afterwards that when the signal was given the darkness had been constant for about ten seconds. The end of totality was unmistakable, being sharply marked, when the counter was calling $2^m\ 22^s$.

Report on the Expedition to Vadsö, in Finmark, to observe the Total Solar Eclipse of 1896 *August* 9. By A. A. Common, LL.D., F.R.S.

In accordance with the arrangements made by the Committee I left England on July 25 in the S.S. *Norse King*, arriving at Vadsö on August 2 with my party.

During totality the sky was cloudy, and no observations were made or photographs taken.

The arrangements were made as follows :—

Observers.—My party consisted of Mr. A. Hinks, of the Observatory, Cambridge ; my son, T. A. Common, Undergraduate, Trinity College, Cambridge ; Major MacMahon, F.R.S. ; Mr. W. H. Wesley, Assistant Secretary R.A.S. ; and my workman, Alfred Wooldridge.

At the request of the Secretary of State for India Mr. K. D. Naegamvala, of the Poona Observatory, India, was attached to the party.

Mr. Naegamvala's object in going to Norway was to gain experience in view of the next Total Solar Eclipse, the central line of totality of which passes near Poona.

Mlle. Klumpké, of the Paris Observatory, also accompanied us.

Instruments.—Two cœlostats with 16-inch plane mirrors were taken, one being the property of the Royal Astronomical Society, the other my own. With these it was proposed to use—

1. The twin telescope as used in Para Caru, Brazil, in 1893. This telescope has an achromatic lens of 3·85 inches aperture and 62 inches focal length, giving an image of the Sun about $\frac{5}{8}$-inch diameter, and also a $4\frac{1}{2}$-inch lens, which in combination with a negative lens of about 8-inch negative focus gives an image about $1\frac{5}{8}$-inch diameter. This combination is arranged to give an image in the same plane as the other. Plate-holders carrying two $6\frac{1}{4} \times 6\frac{1}{4}$ plates fit to the end of the twin tube, and are held in place by a clamp during exposure.

Instead of the ordinary slide, which has to be withdrawn to uncover the plate, a flap is used which opens out into the tube, and may, if needed, be used for making the exposures. The single lens has been used in previous eclipses, and is designated the Abney lens. It is one of a pair forming a photographic lens, formerly belonging to Captain Abney, C.B., now the property of the Royal Astronomical Society. An exactly similar twin telescope was made for and used in the 1893 eclipse at Fundium, West Africa.

2. A 6-inch doublet lens by Grubb, the property of, and kindly lent for this occasion by, Mr. F. McClean, F.R.S. This had a similar negative combination to that of the twin telescope arrangement, but the image in this case was $3\frac{1}{2}$-inch diameter.

This instrument was mounted on a firm wooden framework, and provided with two plate-holders, each carrying three 12 × 10 inch plates. A long frame was attached to the framework, which carried the plate-holders in such a way that the plates could be successively brought to the place required by merely sliding them along the frame, the exposure being made by a hinged shutter near the concave lens.

3. A slit spectroscope with 3½-inch lenses and two 60° light flint prisms.

4. A grating spectroscope, with which it was intended to get the photograph of the spectrum of the corona without a slit.

With instrument No. 1 it was proposed to make exposures of

No. of Slide.	Exposure in Seconds.	Plates.
1	3	Dry collodion plates
2	9	,,
3	27	,,
4	12	Cadett ordinary plates
5	6	,,
6	3	,,

This arrangement uses 60^s of the 104 available at this station. Mr. Hinks had charge of this instrument, Major MacMahon acting as recorder, and two sailors of H.M.S. *Active* handing and receiving the plate-holders. Mr. Hinks found by experience that an allowance of 7^s for changing one slide for another was sufficient.

With instrument No. 2 it was intended to make exposures of

No. of Plate.	Exposure in Seconds.	Plate.
1	3	Dry collodion
2	6	,,
3	27	,,
4	20	Cadett ordinary
5	10	,,
6	5	,,

I took charge of this instrument, Mr. J. J. Atkinson acting as my recorder.

The slit spectroscope had a double dark slide carrying two whole plates, one being dry collodion, the other Cadett ordinary, two exposures of 35^s being given. A. Wooldridge had charge of this instrument.

With the grating spectroscope, which was provided with a 12 × 10 Cadett ordinary plate, it was prepared to take photographs with the same exposure as with the large lens, these instruments being fed by the same cœlostat. T. A. Common had charge of this instrument.

The R.A.S. cœlostat was used with the twin telescope and the slit spectroscope.

The instruments had been erected at Ealing, and carefully focussed and marked, the focussing having been done on the Sun through deep blue glass in the case of the instruments Nos. 1 and 2.

As our arrival on August 2 was at midnight nothing could be done till the next morning, when, in the company of Sir R. S. Ball, I visited the Governor (Prebensen) of Finmark. In fixing upon Vadsö as the site I was largely influenced by a very complete report on the weather and other conditions affecting the various possible positions from Vardö in the north to the Tana river in the west, and the various positions on the south side of the Varanger Fiord kindly obtained for me by Mr. Pirrie, the managing director of the Norse King Steamship Company, who made a special trip to Vadsö in the spring.

Governor Prebensen gave the fullest leave to us to choose any site we might think proper. After visiting the observatory of Dr. Copeland, of Edinburgh, who had chosen a site on the hill about 1¼ miles north of Vadsö, and the observatory of M. Hasselberg, some few yards to the west of Dr. Copeland, I chose a site somewhat nearer the town and near the toboggan slide.

After the selection of this site we returned to the ship about noon, and found that the instruments had been landed on the quay. As soon as possible all was carted up to the site, and work at once begun.

A wooden house had been made in England in parts that could be easily put together, and this was erected, and the corrugated iron roof put on, in a few hours. All the instruments were safely housed by eight o'clock.

Active work was begun early on the 4th. An iron wire attached to posts driven into the ground served to define the ground we wished to reserve, and was quite sufficient in the case of the natives ; but the small cows that grazed on the moor had not the same respect for our landmark. The instruments were erected on stone foundations, the R.A.S. cœlostat being in the corner of the wooden house, the other in a small shelter made for it.

Open frames of wood were made where the telescopes had to be placed for receiving the light from the cœlostats, and filled with some 1½ tons of large stones. These frames made a most substantial foundation for the instruments, complete steadiness being obtained by piling heavy stones on them when fixed in position. A canvas awning was fixed on poles over each instrument, and was found sufficient protection, but, as stated further on, it would be much better to have the whole under one roof.

Owing to the absence of the Sun and the practical impossibility of seeing a star, considerable difficulty was found in getting the cœlostats into position in azimuth. A rough test we

obtained of the Sun's image at an interval of some hours showed a slight shift upwards in both cases. With constant sunshine there would have been no difficulty in getting the adjustments sufficiently correct in a short time. Where this cannot be depended upon it is necessary to allow much more time than we had at our disposal.

In the preparatory work I had the help of several fellow passengers. H.M.S. *Active*, of the Training Squadron, was in the harbour of Vadsö, and Commodore Atkinson very kindly placed a boat's crew and boat at my disposal, and also gave me the services of Yeoman Signaller Simmons and signalman three days before the eclipse, and four sailors on the day of eclipse. The boat was a very great help, as we left the ship at an early hour each morning. Rehearsals were made on the Saturday, and all was ready by Saturday night.

A drenching rain in the early morning of the day of the eclipse got us into the proper frame of mind to meet the disappointment we experienced some hours later.

A short time before totality was due blue sky was seen in the north, and the clouds began to roll away from the Sun at such a rate that it seemed as if it would clear, but by the time these clouds had got away others had come up from the west and covered the Sun.

Mlle. Klumpké had a telescope erected in the north part of our enclosure, and purposed taking time observations of the contacts, assisted by M. Fano.

Sir R. S. Ball had an equatorial telescope in the south side, and undertook to give the signal to stand by about three minutes before totality, and the time of second contact. On hearing this J. S. Simmons began counting seconds 104 to 0 by the help of a dead-beat seconds watch. I had arranged that all should be done as if the sky was clear, and at the word the exposures were all duly made without the least hitch. The darkness did not roll away when our counter gave the last second, and one had a strange feeling that something had gone wrong, for the darkness and the silence were very oppressive. In a few seconds the light returned and the total eclipse was over for us.

On comparing notes Sir R. Ball came to the conclusion that he had given the signal too soon, the faintness of the image as seen through the clouds quite accounting for this.

On developing the plates on my arrival home we found on the first plate exposed to the Abney lens a thin crescent, evidently the last remaining part of the Sun as seen through thick clouds. A copy of this photograph is sent herewith.

Nearly the whole population of Vadsö—some 1,400—turned out to see the eclipse, a great many coming round us. Major Barlow, R.A., kindly undertook, with the help of a staff of special constables, to keep order if needed, but all behaved in the most charming way.

Mr. Wesley was prepared to make sketches of the corona,

but under the circumstances nothing was done. He and others made observations of the appearance of the sky, &c., but nothing of importance was noted.

With the exception of the want of sunshine for adjustment all the arrangements made answered well. The time at our disposal for setting up the instruments was hardly enough, partly owing to the above reason, but the days were very long, and under ordinary circumstances the time would not have been enough.

The instruments all went well. From want of experience in eclipse work I cannot speak with authority on the matter, but I think that there can be no doubt that the cœlostat is the proper instrument for eclipse work. I can easily see the very great additional work we should have had to do if we had been using equatorial mountings. A great improvement might be made by housing the whole of the apparatus under one roof, suitable openings being left for the requisite sky to be seen from the cœlostat.

The arrangement I used with the large lens for sliding the plate-holder along in a frame is very much better than the plan in use with the twin telescope of putting in and taking out each plate-holder separately, a plan necessary in the case of the equatorial mounting for which the twin telescopes were made; but if these are to be used again a sliding arrangement should be used, and I am not sure that it would not be better to still further reduce the hand movement necessary now to expose successive plates by having a mechanical arrangement to do all when once started.

Another point. This eclipse shows that all available stations should be occupied if possible; in this case it would have been well if Bodö had been occupied. On going up the coast I observed the sky in the early morning, and found it very fine indeed, and had it been possible I should have left part of my party at Bodö, Mr. Hinks, in the right scientific spirit, expressing his willingness to forego the pleasures of the longer voyage and to stay there if required. The difficulty of dealing with the instruments separately, however, prevented this being done; nor could I induce any of the many observers on board to stay behind.

Report to the Joint Eclipse Committee on the Expedition to Kiö Island. By Professor J. Norman Lockyer, C.B., F.R.S.

The party consisted of Mr. Fowler, Dr. W. J. S. Lockyer, and myself. As it was impossible for me to leave London before July 22, Mr. Fowler and Dr. W. J. S. Lockyer went on in advance and joined H.M.S. *Volage* at Hammerfest on July 22,

and left the following day for the Varanger Fjord. On July 24 they were landed at Bras Havn, and spent two days in exploring the neighbourhood for a suitable site.

The erection of the instruments was commenced on July 27, and on my arrival at Kiö Island a week later most of them were in adjustment and ready for the eclipse.

The main objects of the expedition were to photograph the spectra of the solar surroundings with prismatic cameras of 6 and 9 inches aperture, and with an integrating spectroscope having two 3-inch prisms of 60°. In addition, about seventy officers and men of H.M.S. *Volage* were trained to make drawings, read thermometers, note the colours of the landscape, &c., and to assist in the manipulation of the larger instruments.

On the morning of the eclipse the sky was almost entirely overcast, the Sun only being visible for a few seconds during the partial phases, so that all work with the instruments was impossible.

Some useful observations of temperature, landscape colours, &c., were secured by the *Volage* observers; and a report upon these, together with a description of the instruments and observing station, will be communicated to the Committee in due course.

To meet the cost of this section of the expedition, including partial instrumental equipment, a grant of 200*l.* was made by the Eclipse Committee. The accounts are not yet completed, as some of the instruments were slightly damaged and the repairs are not finished. The sum granted, however, has certainly not been exceeded, and it is expected that a few pounds will be left over to return to the Committee.

Thanks are due to the Norwegian Government for permission to land on the south side of the Varanger Fjord, to Captain King-Hall, R.N., and the officers and men of H.M.S. *Volage*, who rendered such splendid assistance during the preparations for the eclipse, and to the Orient Steam Navigation Company for the free carriage of some of the instruments, and for twice altering the course of the s.s. *Garonne* to permit landing and embarking off Kiö.

On arriving home I at once communicated to the Royal Society the efficient aid rendered by the officers and men of the *Volage*, as the captain and a large proportion of the crew were to leave the ship on her reaching port.

On the Variation of Uncanonical Arbitrary Constants; with an application to the Planetary Theory. By A. Y. G. Campbell, B.A., Scholar of Trinity College, Cambridge.

(*Communicated by Sir R. S. Ball.*)

In attacking the planetary or lunar theories by the method of the variation of arbitrary constants, it is necessary to evaluate several functions usually denoted by $[a, e]$, &c., unless a canonical set of arbitrary constants is chosen. In this paper I endeavour to show that the equations giving the variations of these constants can be found more quickly without evaluating the functions $[a, e]$, &c. It is necessary to find one function (denoted in this paper by C with a suffix) corresponding to each arbitrary constant. In the first two sections the theory and its application to the elliptic constants of the planetary theory are briefly explained. In the following section it is shown that if any solution of the new equations is found we can proceed to find the equations, giving the variation of the new arbitrary constants. The next approximation can be obtained in a manner similar to that used in the previous case. It is shown also in the last section that in certain cases there exists a method of solution similar to Jacobi's method of solution of the Hamiltonian canonical equations. Among these cases is included the set of equations giving the variations of the elliptic elements in the planetary theory.

§ 1.

Let $\alpha_1, \alpha_2, \ldots \alpha_{2n}$ be the set of arbitrary constants of any solution of the canonical equations

$$\dot{q}_i = \frac{d\mathrm{H}}{dp_i}, \quad -\dot{p}_i = \frac{d\mathrm{H}}{dq_i} (i = 1, 2, \ldots n) \quad \ldots \ldots \quad (1)$$

It is required to find the equations giving the rates of variation of $\alpha_1, \alpha_2, \ldots \alpha_{2n}$ when a disturbing function Ω is added to H.

If L is the Lagrangian function corresponding to H,

$$\frac{d\mathrm{L}}{d\dot{q}_i} = p_i, \quad \frac{d\mathrm{L}}{dq_i} = \dot{p}_i (i = 1, 2, \ldots n);$$

and if α_r is one of the arbitrary constants in terms of which L is supposed to be expressed,

$$\begin{aligned} \frac{d\mathrm{L}}{d\alpha_r} &= \sum_{i=1}^{i=n} \left(\frac{d\mathrm{L}}{dq_i} \frac{dq_i}{d\alpha_r} + \frac{d\mathrm{L}}{d\dot{q}_i} \frac{d\dot{q}_i}{d\alpha_r} \right) \\ &= \sum_{i=1}^{i=n} \left(\dot{p}_i \frac{dq_i}{d\alpha_r} + p_i \frac{d\dot{q}_i}{d\alpha} \right) \\ &= \frac{d}{dt} \left(\sum_{i=1}^{i=n} p_i \frac{dq_i}{d\alpha_r} \right) \end{aligned}$$

the terms in the bracket being expressed in terms of the arbitrary constants, &c. In the above $\dot{p}_i$, $\dot{q}_i$ have been written for the values of

$$\frac{dp_i}{dt}, \quad \frac{dq_i}{dt},$$

when p_i, q_i are expressed in terms of a_1, a_2, . . . a_{2n}, t.

It follows that

$$\sum_{i=1}^{i=n}\left(p_i\frac{dq_i}{da_r}\right)=\int_{t_1}^{t}\frac{dL}{da_r}dt+A_r$$

$\frac{dL}{da_r}$ being expressed in terms of a_1, a_2, . . . a_{2n}, t, and integrated with regard to t explicitly; A_r is a function of a_1, a_2, . . . a_{2n}, and does not contain t explicitly; t_1 may be any function of a_1, a_2, . . . a_{2n}, but must not contain t.

Now

$$\frac{d}{da_r}\int_{t_1}^{t}Ldt=\int_{t_1}^{t}\frac{dL}{da_r}\,dt-(L)_{t=t_1}\frac{dt_1}{da_r};$$

if we put

$$A_r+(L)_{t=t_1}\frac{dt_1}{da_r}+B_r=0$$

we have

$$\left.\begin{aligned}\sum_{i=1}^{i=n}\left(p_i\frac{dq_i}{da_r}\right)&=\frac{d}{da_r}\int_{t_1}^{t}Ldt-B_r\\ \text{and similarly,}\quad \sum_{i=1}^{i=n}\left(p_i\frac{dq_i}{da_s}\right)&=\frac{d}{da_s}\int_{t_1}^{t}Ldt-B_s\end{aligned}\right\}\quad\ldots\ldots\quad(2)$$

If we differentiate the first of these expressions with respect to a_s and the second with respect to a_r, on the supposition that all the functions involved are expressed in terms of a_1, a_2, . . . a_{2n}, t, we find that

$$[a_r, a_s]=\frac{dB_s}{da_r}-\frac{dB_r}{da_s}\quad\ldots\ldots\ldots\ldots\quad(3)$$

where

$$[a_r, a_s]=\sum_{i=1}^{i=n}\left(\frac{dq_i}{da_r}\frac{dp_i}{da_s}-\frac{dq_i}{da_s}\frac{dp_i}{da_r}\right)\quad\ldots\ldots\quad(4)$$

Since B_r, B_s are independent of the time explicitly, it is clear that $[a_r, a_s]$ does not contain t explicitly when it is expressed in terms of a_1, a_2, . . . a_{2n}. It follows also that we can assign any value we please to t in equation (2) as far as regards the determination of B_r.

If

$$C_r = B_r + \frac{dA}{da_r} \quad \ldots\ldots\ldots\ldots \quad (5)$$

where A is any arbitrary function of $a_1, a_2, \ldots a_{2n}$ it is clear that

$$[a_r, a_s] = \frac{dC_s}{da_r} - \frac{dC_r}{da_s} \quad \ldots\ldots\ldots\ldots \quad (6)$$

If we put $t = t_1$ in equation (2)

$$C = -\left[\sum_{i=1}^{i=n}\left(p_i \frac{dq}{da_r}\right) + L\frac{dt_1}{da_r}\right]_{t=t_1} + \frac{dA}{da_r} \quad \ldots\ldots\ldots \quad (7)$$

Having thus determined $[a_r, a_s]$, we can now proceed in the usual manner to find the new equations.

Let the original equations be

$$\dot{q}_i = \frac{d(H+\Omega)}{dp_i}, \quad \dot{p}_i = -\frac{d(H+\Omega)}{dq_i} \; (i = 1, 2, \ldots n) \quad \ldots \quad (8)$$

Then, since $a_1, a_2, \ldots a_{2n}$ have been so chosen that when $q_1, q_2, \ldots q_n, p_1, p_2, \ldots p_n$ are expressed in terms of them and t,

$$\frac{dq_i}{dt} = \frac{dH}{dp_i}, \quad -\frac{dp_i}{dt} = \frac{dH}{dq_i} \; (i = 1, 2, \ldots n)$$

it follows that

$$\sum_{r=1}^{r=2n} \frac{dq_i}{da_r}\dot{a}_r = \frac{d\Omega}{dp_i}, \quad -\sum_{r=1}^{r=2n} \frac{dp_i}{da_r}\dot{a}_r = \frac{d\Omega}{dq_i} \; (i = 1, 2, \ldots n).$$

Multiplying each of these equations by

$$\frac{dp_i}{da_s}, \; \frac{dq_i}{da}$$

respectively, and adding the complete set, we see that

$$\frac{d\Omega}{da_s} = \sum^{r=2n} [a_r, a_s]\dot{a}_r$$

$$= \sum_{r=1}^{r=2n}\left(\frac{dC_s}{da_r} - \frac{dC_r}{da_s}\right)\dot{a}_r$$

$$\therefore \frac{d\Omega}{da_s} = \dot{C}_s - \sum_{r=1}^{r=2n} \frac{dC_r}{da_s}\dot{a}_r \; (s = 1, 2, \ldots n) \quad \ldots\ldots \quad (9)$$

are the required equations.

§ 2. *Application to the Planetary Theory.*

The motion of the planets is governed in general principally by the attractive force of the Sun, which would, if acting alone, cause each planet to describe an ellipse. The deviations from the elliptic orbit are small; it is an advantage to deal with variables whose rates of variation are small, for it is then possible to use methods of approximation. In some expositions of the planetary theory the first change of variables is to the constants of the elliptic orbit. The set which are usually denoted by a, e, ϵ, g, α, ϕ, are uncanonical.

Let the origin of coordinates be taken at the Sun's centre, which is supposed to be at rest or moving with uniform velocity in a straight line. If (x, y, z) are the coordinates of the planet referred to three fixed rectangular axes through the origin

$$\mathrm{L}=\frac{1}{2}(\dot{x}^2+\dot{y}^2+\dot{z}^2)+\frac{1}{r}$$

when the units are properly chosen.
Then

$$p_1=\dot{x},\ p_2=\dot{y},\ p_3=\dot{z}$$

$$\mathrm{H}=\frac{1}{2}(p_1^2+p_2^2+p_3^2)-\frac{1}{r}.$$

Let b denote any one of the constants a, e, ϵ, g, α, ϕ. It is necessary to find

$$\sum_i p_i \frac{dq_i}{db}=\dot{x}\frac{dx}{db}+\dot{y}\frac{dy}{db}+\dot{z}\frac{dz}{db}.$$

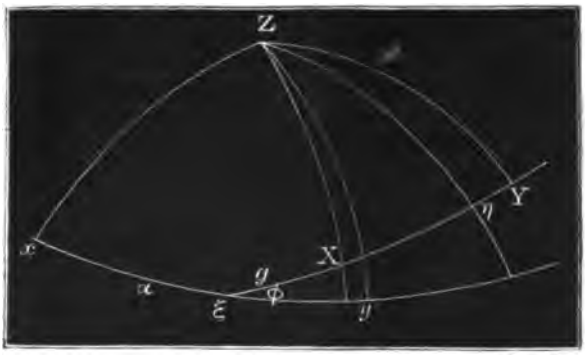
We shall now consider the transformation to new rectangular axes —

$$\left.\begin{aligned} x&=l_1\xi+l_2\eta+l_3\zeta\\ y&=m_1\xi+m_2\eta+m_3\zeta\\ z&=n_1\xi+n_2\eta+n_3\zeta \end{aligned}\right\}$$

where the direction cosines may be functions of the elements, but not of t explicitly.

$$\begin{aligned}\dot{x}\frac{dx}{db}+\dot{y}\frac{dy}{db}+\dot{z}\frac{dz}{db}&=(l_1\dot{\xi}+l_2\dot{\eta}+l_3\dot{\zeta})\left(l_1\frac{d\xi}{db}+l_2\frac{d\eta}{db}+l_3\frac{d\zeta}{db}+\xi\frac{dl_1}{db}+\eta\frac{dl_2}{db}+\zeta\frac{dl}{db}\right)\\ &\quad+(m_1\xi+m_2\dot{\eta}+m_3\dot{\zeta})\left(m_1\frac{d\xi}{db}+m_2\frac{d\eta}{db}+m_3\frac{d\zeta}{db}+\xi\frac{dm_1}{db}+\eta\frac{dm_2}{db}+\zeta\frac{dm_3}{db}\right)\\ &\quad+(n_1\dot{\xi}+n_2\dot{\eta}+n_3\dot{\zeta})\left(n_1\frac{d\xi}{db}+n_2\frac{d\eta}{db}+n_3\frac{d\zeta}{db}+\xi\frac{dn_1}{db}+\eta\frac{dn_2}{db}+\zeta\frac{dn_3}{db}\right)\\ &=\dot{\xi}\frac{d\xi}{db}+\dot{\eta}\frac{d\eta}{db}+\dot{\zeta}\frac{d\zeta}{db}\\ &\quad+(\dot{\xi}\eta-\eta\dot{\xi})\left(l_2\frac{dl_1}{db}+m_2\frac{dm_1}{db}+n_2\frac{dn_1}{db}\right)\\ &\quad+(\eta\dot{\zeta}-\zeta\dot{\eta})\left(l_3\frac{dl_2}{db}+m_3\frac{dm_2}{db}+n_3\frac{dn_2}{db}\right)+(\zeta\dot{\xi}-\xi\dot{\zeta})\left(l_1\frac{dl_3}{db}+m_1\frac{dm_3}{db}+n_1\frac{dn_3}{db}\right).\end{aligned}$$

Let the plane $x\ y$ cut the plane of the ecliptic in the axis ξ, and let the axis η be in the plane of the ecliptic. The angle between x and ξ



is α, and if X denote the axis which is taken along the major axis of the ellipse, the angle between ξ and X is g; the inclination of the ecliptic to the plane $x\ y$ is ϕ; a and e have their usual meanings in an ellipse, and ϵ is the epoch.

The solution of the elliptic motion is given by the following equations—

$$\left.\begin{aligned} \mathrm{X} &= a(\cos u - e) \\ \mathrm{Y} &= a\sqrt{1-e^2}\,.\,\sin u \\ a^{-\frac{1}{2}}t + \epsilon &= u - e\sin u \end{aligned}\right\}$$

$$\left.\begin{aligned} \xi &= \mathrm{X}\cos g - \mathrm{Y}\sin g \\ \eta &= \mathrm{X}\sin g + \mathrm{Y}\cos g \end{aligned}\right\}$$

$$\left.\begin{aligned} x &= \xi\cos\alpha - \eta\sin\alpha\cos\phi \\ y &= \xi\sin\alpha + \eta\cos\alpha\cos\phi \\ z &= \eta\sin\phi \end{aligned}\right\}$$

Considering the description of area we see that

$$\xi\dot{\eta} - \eta\dot{\xi} = \mathrm{X}\dot{\mathrm{Y}} - \mathrm{Y}\dot{\mathrm{X}} = \sqrt{a(1-e^2)}$$

Hence

$$\dot{x}\frac{dx}{d\phi} + \dot{y}\frac{dy}{d\phi} + \dot{z}\frac{dz}{d\phi} = 0$$

$$\dot{x}\frac{dx}{da} + \dot{y}\frac{dy}{da} + \dot{z}\frac{dz}{da} = \sqrt{a(1-e^2)}\,.\,\cos\phi$$

$$\dot{x}\frac{dx}{dg} + \dot{y}\frac{dy}{dg} + \dot{z}\frac{dz}{dg} = \xi\frac{d\xi}{dg} + \dot{\eta}\frac{d\eta}{dg} = \mathrm{X}\dot{\mathrm{Y}} - \mathrm{Y}\dot{\mathrm{X}}$$
$$= \sqrt{a(1-e^2)}$$

and when $b = a$, e or ϵ

$$\dot{x}\frac{dx}{db} + \dot{y}\frac{dy}{db} + \dot{z}\frac{dz}{db} = \dot{\mathrm{X}}\frac{d\mathrm{X}}{db} + \dot{\mathrm{Y}}\frac{d\mathrm{Y}}{db}.$$

Also

$$L = H + \frac{2}{r} = \frac{2}{r} - \frac{1}{2a}.$$

We put

$$t_1 = -ea\dot{t}, \text{ so that } u = 0 \text{ when } t = t_1$$

Then

$$L_{t=t_1} = \frac{2}{a(1-e)} - \frac{1}{2a}.$$

Hence using the formula

$$C_b = -\left[\sum_{i=1}^{i=n} p_i \frac{dq_i}{db} + L\frac{dt_1}{db}\right]_{t=t_1} + \frac{dA}{db}$$

we see that, if we assume A to be independent of g, α, ϕ,

$$C_g = -\sqrt{a(1-e^2)};\ C_\alpha = -\sqrt{a(1-e^2)}\,.\cos\phi;\ C_\phi = 0.$$

We have still to find C_a, C_e, C_ϵ.

Since

$$\left.\begin{aligned} X &= a(\cos u - e), \\ Y &= a\sqrt{1-e^2}\sin u, \\ a - \dot{t}t + \epsilon &= u - e\sin u \end{aligned}\right\}$$

$$(X)_{u=0} = a(1-e),\ (Y)_{u=0} = 0$$

$$\left(\frac{dX}{du}\right)_{u=0} = 0,\ \left(\frac{dY}{du}\right)_{u=0} = a\sqrt{1-e^2}$$

$$(\dot{X})_{u=0} = 0, \text{ and}$$

$$\left(\dot{Y}\frac{dY}{db}\right)_{u=0} = \left[\left(\frac{dY}{du}\right)^2 \frac{du}{dt}\cdot\frac{du}{db}\right]_{u=0} = \sqrt{a}(1+e)\left(\frac{du}{db}\right)_{u=0}$$

Hence

$$C_b = -\left(\frac{2}{a(1-e)} - \frac{1}{2a}\right)\frac{dt_1}{db} - \sqrt{a}(1+e)\left(\frac{du}{db}\right)_{\substack{u=0\\t=t_1}} + \frac{dA}{db}$$

$$C_a = \frac{3}{2}\epsilon\frac{1}{\sqrt{a}}\left(\frac{2}{1-e} - \frac{1}{2}\right) - \frac{3}{2}\frac{e}{\sqrt{a}}\frac{1+e}{1-e} + \frac{dA}{da} = \frac{3}{4}\frac{e}{\sqrt{a}} + \frac{dA}{da}.$$

$$C_e = \frac{dA}{de}$$

$$C_\epsilon = \sqrt{a}\left(\frac{2}{1-e} - \frac{1}{2}\right) - \sqrt{a}\frac{1+e}{1-e} + \frac{dA}{de} = \frac{\sqrt{a}}{2} + \frac{dA}{de}.$$

If we put $A = -\frac{1}{2}\sqrt{a}\,.\,\epsilon$, we see that

$$C_a = \frac{1}{2}\frac{e}{\sqrt{a}},\ C_e = 0,\ C_\epsilon = 0,$$

$$C_g = -\sqrt{a(1-e^2)},\ C_\alpha = -\sqrt{a(1-e^2)}\cos\phi,\ C_\phi = 0.$$

Hence from equation (9), the new equations are

$$\left.\begin{aligned}
\frac{d\Omega}{da} &= \frac{1}{2}a^{-\frac{1}{2}}\dot{\epsilon} + \frac{1}{2}a^{-\frac{1}{2}}\sqrt{1-e^2}(\dot{g}+\dot{a}\cos\phi)\\
\frac{d\Omega}{de} &= -a^{\frac{1}{2}}\frac{e}{\sqrt{1-e^2}}(\dot{g}+\dot{a}\cos\phi)\\
\frac{d\Omega}{d\epsilon} &= \frac{1}{2}a^{-\frac{1}{2}}\dot{a}\\
\frac{d\Omega}{dg} &= -\frac{1}{2}a^{-\frac{1}{2}}\sqrt{1-e^2}\,.\,\dot{a} + a^{\frac{1}{2}}\frac{e}{\sqrt{1-e^2}}\,.\,\dot{e}\\
\frac{d\Omega}{da} &= -\frac{1}{2}a^{-\frac{1}{2}}\sqrt{1-e^2}\,.\,\dot{a}\cos\phi + a^{\frac{1}{2}}\frac{e}{\sqrt{1-e^2}}\dot{e}\cos\phi + \sqrt{a}(\sqrt{1-e^2})\sin\phi\\
\frac{d\Omega}{d\phi} &= -\sqrt{a}(\sqrt{1-e^2})\,.\,\sin\phi\,.\,\dot{a}.
\end{aligned}\right\}$$

§ 3. *A Method of Successive Approximation.*

In proceeding to consider consecutive terms of the disturbing function, it is assumed that a solution containing $2n$ arbitrary constants $\beta_1, \beta_2, \ldots \beta_{2n}$ has been found of the equations

$$\frac{d\Omega_1}{da_s} = \dot{C}_s - \sum_{r=1}^{r=2n}\frac{dC_r}{da_s}\dot{a}_r, \quad (s = 1, 2, \ldots 2n) \quad . \quad . \quad . \quad . \quad . \quad (10)$$

and it is required to find the equations for $\dot{\beta}_1, \dot{\beta}_2, \ldots \dot{\beta}_{2n}$ when Ω_2 is added to Ω_1.

Let

$$L_1 = \Omega_1 + \sum_{r=1}^{r=2n} C_r\,\dot{a}_r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$\begin{aligned}
\frac{dL_1}{d\beta_k} &= \sum_{s=1}^{s=2n}\frac{d\Omega_1}{da_s}\frac{da_s}{d\beta_k} + \sum_{r=1}^{r=2n}\sum_{s=1}^{s=2n}\frac{dC_r}{da_s}\dot{a}_r\frac{da_s}{d\beta_k} + \sum_{r=1}^{r=2n}C_r\frac{d\dot{a}_1}{d\beta_k}\\
&= \sum_{s=1}^{s=2n}\left[\dot{C}_s\frac{da_s}{d\beta_k} + C_s\frac{d\dot{a}_s}{d\beta_k}\right], \text{ by (10)}\\
&= \frac{d}{dt}\left(\sum_{s=1}^{s=2n}C_s\frac{da}{d\beta_k}\right)
\end{aligned}$$

the terms in the bracket being expressed in terms of $\beta_1, \beta_2, \ldots \beta_{2n}$, t, and $\dot{C}_s$, $\dot{a}_s$ being written in the above for the values of

$$\frac{dC_s}{dt}, \quad \frac{da_s}{dt}$$

when C_s, a_s are expressed in terms of $\beta_1, \beta_2, \ldots \beta_{2n}$, t.

It follows that

$$\sum_{s=1}^{s=2n}C_s\frac{da_s}{d\beta_k} = \int_{t_0}^{t}\frac{dL_1}{d\beta_k}dt + D_k,$$

$\frac{dL_1}{d\beta_k}$ being expressed in terms of $\beta_1, \beta_2, \ldots \beta_{2n}, t$, and integrated with regard to t explicitly; D_k is a function of $\beta_1, \beta_2, \ldots \beta_{2n}$, but does not contain t explicitly; t_1 may be any function of $\beta_1, \beta_2, \ldots \beta_{2n}$, but must not contain t.

If

$$D_k + (L_1)_{t=t_1} \frac{dt_1}{d\beta_k} + E_k = 0$$

then

$$\left.\begin{aligned} \sum_{s=1}^{s=2n} \left(C_s \frac{da_s}{d\beta_k}\right) &= \frac{d}{d\beta_k}\int_{t_1}^{t} L_1\, dt - E_k \\ \text{similarly} \quad \sum_{s=1}^{s=2n} \left(C_s \frac{da_s}{d\beta_j}\right) &= \frac{d}{d\beta_j}\int_{t_1}^{t} L_1\, dt - E_j \end{aligned}\right\} \quad \ldots\ldots (12)$$

Hence

$$[\beta_k, \beta_j] = \frac{dE_j}{d\beta_k} - \frac{dE_k}{d\beta_j} \quad \ldots\ldots\ldots (13)$$

where

$$[\beta_k, \beta_j] \equiv \sum_{s=1}^{s=2n} \left(\frac{dC_s}{d\beta_j}\frac{da_s}{d\beta_k} - \frac{dC_s}{d\beta_k}\cdot\frac{da_s}{d\beta_j}\right) \quad \ldots\ldots (14)$$

Since E_j, E_k are independent of t explicitly, it follows that $[\beta_k, \beta_j]$ does not contain t explicitly, when expressed in terms of $\beta_1, \beta_2, \ldots \beta_{2n}$. It follows, also, that, as far as regards the determination of E_k, we can assign any value we please to t in equation (12).

If

$$F_k = E_k + \frac{dB}{d\beta_k} \quad \ldots\ldots (15)$$

when B is any arbitrary function of $\beta_1, \beta_2, \ldots \beta_{2n}$, it is clear that

$$[\beta_k, \beta_j] = \frac{dF_j}{d\beta_k} - \frac{dF_k}{d\beta_j} \quad \ldots\ldots (16)$$

and if we put $t = t_1$ in equation (12)

$$F_k = -\left[\sum_{s=1}^{s=2n}\left(C_s\frac{da_s}{d\beta_k}\right) + L_1\frac{dt_1}{d\beta_k}\right]_{t=t} + \frac{dB}{d\beta_k} \quad \ldots\ldots (17)$$

Having thus determined $[\beta_k, \beta_j]$ we can now proceed to find the new equations.

Let the original equations be

$$\frac{d(\Omega_1 + \Omega_2)}{da_s} = \dot{C}_s - \sum_{r=1}^{r=2n}\frac{dC_r}{da_s}\dot{a}_r, \ (s = 1, \ldots 2n) \quad \ldots\ldots (18)$$

Then, since $\beta_1, \beta_2, \ldots \beta_{2n}$ have been so chosen that when $a_1, a_2, \ldots a_{2n}, C_1, C_2, \ldots C_{2n}$, are expressed in terms of them and t

$$\frac{d\Omega_1}{da_s} = \frac{dC_s}{dt} - \sum_{r=1}^{r=2n} \frac{dC_r}{da_s} \cdot \frac{da_r}{dt}, \quad (s = 1, 2, \ldots 2n)$$

it follows that

$$\frac{d\Omega_2}{da_s} = \sum_{k=1}^{k=2n} \frac{dC_s}{d\beta_k} \dot{\beta}_k - \sum_{k=1}^{k=2n} \sum_{r=1}^{r=2n} \frac{dC_r}{da_s} \cdot \frac{da_r}{d\beta_k} \cdot \dot{\beta}_k.$$

Multiplying this equation by

$$\frac{da_s}{d\beta_j} \quad (s = 1, 2, \ldots 2n)$$

and adding the complete set we see that

$$\begin{aligned}
\frac{d\Omega_2}{d\beta_j} &= \sum_{k=1}^{k=2n} \sum_{s=1}^{s=2n} \frac{dC_s}{d\beta_k} \cdot \frac{da_s}{d\beta_j} \dot{\beta}_k \\
&\quad - \sum_{k=1}^{k=2n} \sum_{r=1}^{r=2n} \sum_{s=1}^{s=2n} \frac{dC_r}{da_s} \cdot \frac{da_s}{d\beta_j} \cdot \frac{da_r}{d\beta_k} \cdot \dot{\beta}_k \\
&= \sum_{k=1}^{k=2n} \sum_{s=1}^{s=2n} \frac{dC_s}{d\beta_k} \frac{da_s}{d\beta_j} \dot{\beta}_k \\
&\quad - \sum_{k=1}^{k=2n} \sum_{r=1}^{r=2n} \frac{dC_r}{d\beta_j} \frac{da_r}{d\beta_k} \dot{\beta}_k \\
&= \sum_{k=1}^{k=2n} [\beta_k, \beta_j] \dot{\beta}_k \\
&= \sum_{k=1}^{k=2n} \left(\frac{dF_j}{d\beta_k} - \frac{dF_k}{d\beta_j} \right) \dot{\beta}_k
\end{aligned}$$

$$\therefore \frac{d\Omega_2}{d\beta_j} = \dot{F}_j - \sum_{k=1}^{k=2n} \frac{dF_k}{d\beta_j} \dot{\beta}_k, \quad (j = 1, 2, \ldots 2n) \quad \ldots \quad (19)$$

are the required equations.

It is clear that that this theorem includes that of §1 as a particular case. If it is possible to express $\beta_1, \beta_2, \ldots \beta_{2n}$ in terms of $F_1, F_2, \ldots F_{2n}$, we see, by multiplying equation (19) by

$$\frac{d\beta_j}{dF_m}$$

and adding, that

$$-\frac{d\Omega_2}{dF_m} = \dot{\beta}_m - \sum_{k=1}^{k=2n} \frac{d\beta_k}{dF_m} \cdot \dot{F}_k, \quad (m = 1, 2 \ldots 2n) \quad \ldots \quad (20)$$

There is a species of reciprocity between the set of variables $(F_1, F_2, \ldots F_{2n})$ and the set $(\beta_1, \beta_2, \ldots \beta_{2n})$.

From a consideration of the coefficient of $\dot{F}_s$ in (20), it is clear that

$$[F_r, F_s] = -\frac{d\beta_s}{dF_r} + \frac{d\beta_r}{dF_s}.$$

§ 4. If n of the functions denoted by C, say $C_{n+1}, C_{n+2} \ldots C_{2n}$, are functions of the n a's only, which do not correspond to them, viz. $a_1, a_2, \ldots a_n$, it is possible to indicate a method of solution of the equations:

$$\frac{d\Omega}{da_s} = \dot{C}_s - \sum_{r=1}^{r=2n} \frac{dC_r}{da_s} \cdot \dot{a}_r, \ (s = 1, 2, \ldots 2n) \quad \ldots \quad (9)$$

which is similar to Jacobi's method of solution of the canonical equations.

Let $\beta_1, \beta_2, \ldots \beta_n, \gamma_1, \gamma_2, \ldots \gamma_n$, be $2n$ variables connected with $a_1, a_2, \ldots a_{2n}$ by the equations

$$\left.\begin{aligned} \frac{d\psi}{da_i} &= C_i - \sum_{r=n+1}^{r=2n} a_r \frac{dC_r}{da_i} \\ \frac{d\psi}{d\beta_i} &= \gamma_i \end{aligned}\right\} (i = 1, 2, \ldots n) \quad \ldots \quad (21)$$

where ψ is a function of $a_1, a_2, \ldots a_n, \beta_1, \beta_2, \ldots \beta_n, t$ only.

Let δ denote an arbitrary variation of the variables.

Then since

$$\delta C_r = \sum_{i=1}^{i=n} \frac{dC_r}{da_i} \delta a_i + \frac{dC_r}{dt} \delta t$$

if C_r do not contain $a_{n+1}, a_{n+2}, \ldots a_{2n}$, where $r = n+1, n+2, \ldots 2n$.

$$\delta\psi = \sum_{i=1}^{i=n} \left(\frac{d\psi}{da_i} \delta a_i + \frac{d\psi}{d\beta_i} \delta\beta_i \right) + \frac{d\psi}{dt} \delta t$$

$$= \sum_{i=1}^{i=n} (C_i \ \delta a_i + \gamma_i \delta\beta_i) - \sum_{i=n+1}^{i=2n} a_i \delta \ C_i + \phi \delta t$$

when

$$\phi \equiv \frac{d\psi}{dt} + \sum_{i=n+1}^{i=2n} a_i \frac{dC}{dt} \quad \ldots \quad (22)$$

Let Δ denote another independent arbitrary variation.

Then

$$\Delta\delta\psi = \sum_{i=1}^{i=n} [\Delta C_i \delta a_i + \Delta\gamma_i \delta\beta_i + C_i \Delta\delta a_i + \gamma_i \Delta\delta\beta_i]$$

$$- \sum_{i=n+1}^{i=2n} (\Delta a_i \delta C_i + a_i \Delta\delta C_i) + \Delta\phi \ . \ \delta t + \phi \ . \ \Delta\delta t$$

Similarly

$$\delta\Delta\psi = \sum_{i=1}^{i=n} [\delta C_i \Delta a_i + \delta\gamma_i \Delta\beta_i + C_i \delta\Delta a_i + \gamma_i \delta\Delta\beta_i]$$

$$- \sum_{i=n+1}^{i=2n} [\delta a_i \Delta C_i + a_i \delta\Delta C_i] + \delta\phi \ . \ \Delta t + \phi \ . \ \delta\Delta t.$$

But

$$\Delta\delta\psi = \delta\Delta\psi,\ \delta\Delta a_i = \Delta\delta a_i,\ \&c.$$

Hence

$$\sum_{i=1}^{i=2n}[\delta a_i \Delta C_i - \Delta a_i \delta C_i] + \sum_{r=1}^{r=n}[-\delta\gamma_r \Delta\beta_r + \Delta\gamma_r \delta\beta_r] + \Delta\phi \,.\, \delta t - \delta\phi \,.\, \Delta t = 0. \quad (23)$$

Now $a_1, a_2, \ldots a_{2n}$ can be expressed in terms of $\beta_1, \beta_2, \ldots \beta_n, \gamma_1, \gamma_2, \ldots \gamma_n, t$, and *vice versâ*.

Let $(\ )'$ denote that the quantity enclosed in the bracket is expressed in terms of $\beta_1, \beta_2, \ldots \beta_n, \gamma_1, \gamma_2, \gamma_n, t$; and let all quantities except ψ, which are not enclosed in $(\ )'$, be in future expressed in terms of $a_1, a_2, \ldots a_{2n}, t$; but let ψ be in all cases expressed in terms of $a_1, a_2, \ldots a_n, \beta_1\ \beta_2, \ldots \beta_n, t$.

Then

$$\Delta a_i = \sum_{r=1}^{r=n}\left[\frac{d(a_i)'}{d\beta_r}\Delta\beta_r + \frac{d(a_i)'}{d\gamma_r}\Delta\gamma_r\right] + \frac{d(a_i)'}{dt}\Delta t$$

$$\delta\beta_r = \sum_{i=1}^{i=2n}\left[\frac{d\beta_r}{da_i}\,\delta a_i\right] + \frac{d\beta_r}{dt}\delta t,\ \&c.$$

Equation (23) can then be written

$$\sum_{i=1}^{i=2n}\left[\delta a_i\left\{\sum_{r=1}^{r=n}\left(\frac{d(C_i)'}{d\beta_r}\Delta\beta_r + \frac{d(C_i)'}{d\gamma_r}\Delta\gamma_r\right) + \frac{d(C_i)'}{dt}\Delta t\right\}\right.$$

$$-\sum_{s=1}^{s=2n}\left[\sum_{r=1}^{r=n}\left\{\frac{d(a_s)'}{d\beta_r}\Delta\beta_r + \frac{d(a_s)'}{d\gamma_r}\Delta\gamma_r\right\} + \frac{d(a_s)'}{dt}\Delta t\right]\cdot\left[\sum_{i=1}^{i=n}\frac{dC_s}{da_i}\delta a_i + \frac{dC_s}{dt}\delta t\right]$$

$$+\sum_{r=1}^{r=n}\left[\Delta\gamma_r\left\{\sum_{i=1}^{i=2n}\frac{d\beta_r}{da_i}\delta a_i + \frac{d\beta_r}{dt}\delta t\right\}\right.$$

$$\left.\left.-\Delta\beta_r\left\{\sum_{i=1}^{i=2n}\frac{d\gamma_r}{da_i}\delta a_i + \frac{d\gamma_r}{dt}\delta t\right\}\right]\right.$$

$$+\delta t\left\{\sum_{r=1}^{r=n}\left(\frac{d(\phi)'}{d\beta_r}\Delta\beta_r + \frac{d(\phi)'}{d\gamma_r}\Delta\gamma\right) + \frac{d(\phi)'}{dt}\Delta t\right\}$$

$$-\Delta t\left\{\sum_{i=1}^{i=2n}\frac{d\phi}{da_i}\delta a_i + \frac{d\phi}{dt}\delta t\right\} = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

But the variations

$$\delta a_1, \delta a_2, \ldots \delta a_{2n}, \delta t, \Delta\beta_1, \Delta\beta_2, \ldots \Delta\beta_n, \Delta\gamma_1, \Delta\gamma_2, \ldots \Delta\gamma_n, \Delta t$$

are all arbitrary and independent; each coefficient of these quantities in equation (24) must therefore be zero.

Hence we find :

$$\left.\begin{aligned}\frac{d(C_i)'}{d\beta_r}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{d\beta_r}\cdot\frac{dC_s}{da_i}-\frac{d\gamma_r}{da_i}&=0\\ \frac{d(C_i)'}{d\gamma_r}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{d\gamma_r}\cdot\frac{dC_s}{da_i}+\frac{d\beta_r}{da_i}&=0\end{aligned}\right\}\quad\ldots\ldots\quad(25)$$

$$\frac{d(C_i)'}{dt}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{dt}\cdot\frac{dC_s}{da_i}-\frac{d\phi}{da_i}=0\quad\ldots\ldots\quad(26)$$

$$\left.\begin{aligned}-\frac{d\gamma_r}{dt}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{d\beta_r}\cdot\frac{dC_s}{dt}+\frac{d(\phi)'}{d\beta_r}&=0\\ \frac{d\beta_r}{\delta t}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{d\gamma_r}\cdot\frac{dC_s}{dt}+\frac{d(\phi)'}{d\gamma_r}&=0\end{aligned}\right\}\quad\ldots\ldots\quad(27)$$

$$\frac{d(\phi)'}{dt}-\sum_{s=1}^{s=2n}\frac{d(a_s)'}{dt}\cdot\frac{dC_s}{dt}-\frac{d\phi}{dt}=0\quad\ldots\ldots\quad(28)$$

Now the original equations are

$$\frac{d\Omega}{da_s}=\dot{C}_s-\sum_{r=1}^{r=2n}\frac{dC_r}{da_s}\dot{a}_r,\ (s=1,\ 2,\ \ldots\ 2n)\quad\ldots\ldots\quad(9)$$

Hence

$$\begin{aligned}\frac{d(\Omega)'}{d\beta_r}&=\sum_{s=1}^{s=2n}\left[\frac{d(a_s)'}{d\beta_r}\cdot\dot{C}_s-\sum_{i=1}^{i=2n}\frac{dC_i}{da_s}\cdot\frac{d(a_s)'}{d\beta_r}\cdot\dot{a}_i\right]\\ &=\sum_{s=1}^{s=2n}\left[\frac{d(a_s)'}{d\beta_r}\cdot\dot{C}_s\right]-\sum_{i=1}^{i=2n}\dot{a}_i\frac{d(C_i)'}{d\beta_r}\\ &=\sum_{s=1}^{s=2n}\left[\frac{d(a_s)'}{d\beta_r}\cdot\dot{C}_s-\frac{d(C_s)'}{d\beta_r}\cdot\dot{a}_s\right]\\ &=\sum_{s=1}^{s=2n}\left[\frac{dC_s}{dt}\cdot\frac{d(a_s)'}{d\beta_r}+\sum_{i=1}^{i=2n}\frac{dC_s}{da_i}\dot{a}_s\frac{d(a_s)'}{d\beta_r}\right]\\ &\quad-\sum_{i=1}^{i=2n}\left[\dot{a}_i\left\{\sum_{s=1}^{s=2n}\frac{d(a_s)'}{d\beta_r}\cdot\frac{dC_s}{da_i}+\frac{d\gamma_r}{da_i}\right\}\right]\ \text{by (25)}\\ &=-\frac{d\gamma_r}{dt}+\frac{d(\phi)'}{d\beta_r}-\sum_{i=1}^{i=2n}\dot{a}_i\frac{d\gamma_r}{da_i},\ \text{by (27)}\end{aligned}$$

whence we obtain

$$\left.\begin{aligned}\dot{\gamma}_r&=-\frac{d}{d\beta_r}(\phi-\Omega)'\\ \text{Similarly}\qquad\dot{\beta}_r&=\frac{d}{d\gamma_r}(\phi-\Omega)'\end{aligned}\right\}\ (r=1,\ 2,\ \ldots\ n).\quad(29)$$

These new equations are canonical.

If $\phi=\Omega$, we see that $\beta_1,\ \beta_2,\ \ldots\ \beta_n,\ \gamma_1,\ \gamma_2,\ \ldots\ \gamma_n$, form a

canonical set of arbitrary constants, the solution being given by the equations

$$\left.\begin{aligned}\frac{d\psi}{da_i} &= C_i - \sum_{r=n+1}^{r=2n} \alpha_r \frac{dC_r}{da_i} \\ \frac{d\psi}{d\beta_i} &= \gamma_i\end{aligned}\right\} \quad (i = 1, 2, \ldots n) \quad . \quad . \quad . \quad . \quad (21)$$

when

$$\phi = \frac{d\psi}{dt} + \sum_{i=n+1}^{i=2n} \alpha_i \frac{dC_i}{dt} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

From the equations

$$\frac{d\psi}{da_i} = C_i - \sum_{r=n+1}^{r=2n} \alpha_r \frac{dC_r}{da_i}, \quad (i = 1, 2, \ldots n)$$

we can in general find α_{n+1}, α_{n+2}, . . α_{2n} in terms of

$$a_1, a_2, \ldots a_n, \frac{d\psi}{da_1}, \frac{d\psi}{da_2}, \ldots \frac{d\psi}{da_n}, t.$$

If these values are substituted in the equation

$$\frac{d\psi}{dt} + \sum_{i=1}^{i=n} \alpha_i \frac{dC_i}{dt} = \Omega \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (30)$$

we obtain a differential equation of the first order, for ψ in terms of $a_1, a_2, \ldots a_n, t$. If any complete solution of this equation, containing n arbitrary constant $\beta_1, \beta_2, \ldots \beta_n$ be found, the solution of the equations (9) is given by equations (21).

If, now, a further term Ω_1 is added to Ω, the equations for the variations of the arbitrary constants are (by [29]) seen to be

$$\left.\begin{aligned}\dot{\gamma}_r &= \frac{d\Omega_1}{d\beta_r} \\ -\dot{\beta}_r &= \frac{d\Omega_1}{d\gamma_r}\end{aligned}\right\} (r = 1, 2, \ldots n) \quad . \quad . \quad . \quad . \quad . \quad . \quad (31)$$

which form a canonical set.

In particular, if C_{n+1}, C_{n+2}, . . . C_{2n}, are all zero or definite constants, we see, by putting

$$\psi = \sum_{i=1}^{i=n} \alpha_i \beta_i$$

in which $\phi = 0$, that $a_1, a_2, \ldots a_n$, $C_1, C_2, \ldots C_n$, in this case form a canonical set of variables. For example, in the case of the planetary theory,

$$a, \quad g, \quad a$$
$$\tfrac{1}{2}\frac{\epsilon}{\sqrt{a}}, \quad -\sqrt{a(1-e^2)}, \quad -\sqrt{a(1-e^2)} \cdot \cos\phi$$

form a canonical set of arbitrary constants of the elliptic motion.

Note on Mr. A. Y. G. Campbell's paper "On the Variation of Uncanonical Arbitrary Constants, with an Application to the Planetary Theory." By Sir Robert S. Ball, LL.D., F.R.S.

The object of this note is to set down another method by which the calculation of Lagrange's "parentheses" in the planetary theory can be effected very simply. The method was suggested by a manuscript which Mr. Campbell kindly communicated to me. I have also to acknowledge the assistance derived from the instructive remarks of Mr. Cowell and Mr. Whittaker, to whom, as well as to Mr. Campbell, it has been my privilege to have lectured at Cambridge.

Adopting the notation of Mr. Campbell's manuscript, we put

$$\frac{\partial(x, \dot{x})}{\partial(\lambda, \mu)} \text{ for } \frac{dx}{d\lambda} \cdot \frac{d\dot{x}}{d\mu} - \frac{dx}{d\mu} \cdot \frac{d\dot{x}}{d\lambda},$$

where λ, μ are any two of the six arbitrary constants.

We thus have the expression for the "parenthesis"

$$[\lambda, \mu] = \frac{\partial(x, \dot{x})}{\partial(\lambda, \mu)} + \frac{\partial(y, \dot{y})}{\partial(\lambda, \mu)} + \frac{\partial(z, \dot{z})}{\partial(\lambda, \mu)}.$$

We now make the transformation to another set of rectangular coordinates x_1, y_1, z_1, where

$$\begin{aligned} x &= l_1 x_1 + l_2 y_1 + l_3 z_1 \\ y &= m_1 x_1 + m_2 y_1 + m_3 z_1 \\ z &= n_1 x_1 + n_2 y_1 + n_3 z_1 \end{aligned}$$

It is unnecessary to write down the general result. For the planetary theory we take the special case where

$$\begin{array}{lll} l = \cos a & l_2 = -\sin a \cos \phi & l_3 = 0 \\ m_1 = \sin a & m_2 = \cos a \cos \phi & m_3 = 0 \\ n_1 = 0 & n_2 = \sin \phi & n_3 = 0 \end{array}$$

And if we express x_1 by ξ and y_1 by η we get after a little reduction

$$[\lambda, \mu] = \frac{\partial(\xi, \dot{\xi})}{\partial(\lambda, \mu)} + \frac{\partial(\eta, \dot{\eta})}{\partial(\lambda, \mu)} - \sin \phi \, (\xi\dot{\eta} - \dot{\xi}\eta) \frac{\partial(a, \phi)}{\partial(\lambda, \mu)}$$

$$+ \cos \phi \, \frac{da}{d\lambda} \frac{d}{d\mu} (\xi\dot{\eta} - \dot{\xi}\eta) - \cos \phi \, \frac{da}{d\mu} \frac{d}{d\lambda} (\xi\dot{\eta} - \dot{\xi}\eta)$$

We now transform to two new variables X and Y given by the equations

$$\begin{aligned} \xi &= X \cos g - Y \sin g \\ \eta &= X \sin g + Y \cos g \end{aligned}$$

Also from the known properties of elliptic motion

$$\xi\dot{\eta} - \eta\dot{\xi} = \sqrt{a}(1-e^2) = h,$$

whence the general symbolic representation of a "parenthesis"

$$[\lambda, \mu] = \frac{\partial(X, \dot{X})}{\partial(\lambda, \mu)} + \frac{\partial(Y, \dot{Y})}{\partial\lambda, \mu)} - h \sin\phi \frac{\partial(a, \phi)}{\partial(\lambda, \mu)} + \cos\phi \frac{\partial(a, h)}{\partial(\lambda, \mu)} + \frac{\partial(g, h)}{\partial(\lambda, \mu)}.$$

It will now be convenient to divide the fifteen "parentheses" into two groups, those which contain ϵ and those which do not. Taking the former first, we have

$$[\epsilon, \mu] = \frac{\partial(X, \dot{X})}{\partial(\epsilon, \mu)} + \frac{\partial(Y, \dot{Y})}{\partial(\epsilon, \mu)},$$

for obviously the three latter terms in the general expression do not contribute.

As ϵ only occurs in the expression $a^{-\frac{1}{2}}t + \epsilon$, and as t is never found except in this expression

$$\frac{dX}{d\epsilon} = a^{\frac{1}{2}}\dot{X} \qquad \frac{dY}{d\epsilon} = a^{\frac{1}{2}}\dot{Y}$$

$$\frac{d\dot{X}}{d\epsilon} = a^{\frac{1}{2}}\ddot{X} \qquad \frac{d\dot{Y}}{d\epsilon} = a^{\frac{1}{2}}\ddot{Y}$$

whence we easily find

$$\frac{d\dot{X}}{d\epsilon} = -\frac{a^{\frac{1}{2}}}{\rho^3}X; \quad \frac{d\dot{Y}}{d\epsilon} = -\frac{a^{\frac{1}{2}}}{\rho^3}Y$$

We thus have

$$[\epsilon, \mu] = \frac{1}{2}a^{\frac{1}{2}}\frac{d}{d\mu}(\dot{X}^2 + \dot{Y}^2) + \frac{1}{2}a^{\frac{1}{2}}\frac{1}{\rho^3}\frac{d}{d\mu}(X^2 + Y^2) = \frac{1}{2}a^{-\frac{1}{2}}\frac{da}{d\mu}.$$

For those parentheses $[\lambda, \mu]$ whereof neither is ϵ the following considerations will simplify the result.

In the values of $X, \dot{X}, Y, \dot{Y}, t$ and ϵ enter only by powers of the exponential $e^{i(a^{-\frac{1}{2}}t+\epsilon)}$, where e is the base of natural logs. If this be differentiated with respect to constants which are neither a nor ϵ, this exponential is unaffected. But we know that the time disappears from the parenthesis; therefore it is immaterial what be the value of $a^{-\frac{1}{2}}t + \epsilon$, and we may accordingly take both t and ϵ zero. If, however, the exponential be differentiated with respect to a, then we have terms like $te^{i(a^{-\frac{1}{2}}t+\epsilon)}$. But such terms must be mutually destructive, for the exponential terms simply can never annul them. We need therefore never have formed such terms. Hence we may *before* differentiation make both t and ϵ zero. Hence both $\dot{X}$ and $\dot{Y}$ may be treated as non-existent, and

$$\frac{\partial(X, \dot{X})}{\partial(\lambda, \mu)} + \frac{\partial(Y, \dot{Y})}{\partial(\lambda, \mu)}$$

will be zero whenever ϵ is neither λ nor μ.

We have thus reduced the formulæ for the parentheses to the simple forms following :—

$$[\epsilon, \mu] = \frac{1}{2} a^{-\frac{1}{2}} \frac{da}{d\mu} \text{ for all which contain } \epsilon$$

$$[g, \mu] = \frac{\partial(g, h)}{\partial(g, \mu)} \quad \ldots\ldots\ldots g$$

$$[\phi, \mu] = h \sin \phi \frac{\partial(\phi, a)}{\partial(\phi, \mu)} \quad \ldots\ldots \phi$$

$$[\lambda, \mu] = \cos\phi \frac{\partial(a, h)}{\partial(\lambda, \mu)} \text{ for all which contain only } a, e, a$$

Perhaps the most instructive form is that which comprises *all* the fifteen parentheses in the general expression

$$[\lambda, \mu] = \tfrac{1}{2} a^{-\frac{1}{2}} \frac{\partial(\epsilon, a)}{\partial(\lambda, \mu)} + \frac{\partial(g, h)}{\partial(\lambda, \mu)} + \cos\phi \frac{\partial(a, h)}{\partial(\lambda, \mu)} - h \sin \phi \frac{\partial(a, \phi)}{\partial(\lambda, \mu)}.$$

We thus obtain by inspection

$[\epsilon, a] = \frac{1}{2} a^{-\frac{1}{2}}$	$[\epsilon, e] = 0$	$[\epsilon, a] = 0$	$[\epsilon, \phi] = 0$	$[\epsilon, g] = 0$
$[g, a] = \frac{dh}{da}$	$[g, e] = \frac{dh}{de}$	$[g, a] = 0$	$[g, \phi] = 0$	
$[\phi, a] = 0$	$[\phi, e] = 0$	$[\phi, a] = h \sin \phi$		
$[e, a] = 0$	$[a, a] = \cos\phi \frac{dh}{da}$	$[a, e] = \cos\phi \frac{dh}{de}$		

where

$$h = \sqrt{a(1-e^2)}; \quad \frac{dh}{da} = \frac{1}{2} a^{-\frac{1}{2}} \sqrt{1-e^2}; \quad \frac{dh}{de} = -\frac{a^{\frac{1}{2}} e}{\sqrt{1-e^2}}$$

thus giving the well-known expressions in the Planetary Theory.

On Differential Refraction to Terms of Higher Orders than the First. By H. H. Turner, M.A., B.Sc., Savilian Professor.

1. For moderate zenith distances the differential refraction on, say, a photographic plate is expressed with sufficient accuracy by the first powers of the relative coordinates when the field is not too large ; but a plate may be exposed at a considerable zenith distance for the purpose of measuring parallax or some other reason, and again the field photographed may be of considerable extent. In such cases the first powers of the coordinates no longer afford a sufficiently accurate approximation, and we must take in

higher powers. Investigations of this kind have been made by Rambaut (*Ast. Nach.* 3125), Kapteyn (*Bull. Com. Perm.* T. III.), and others; but I cannot but feel that the formulæ are greatly simplified by the use of rectangular coordinates such as I have advocated in previous papers (*M.N.* liv. p. 11, liv. p. 489, lv. p. 102, lv. p. 419, &c.), and in the present paper the differential refraction will be investigated by the use of such coordinates.

2. In *M.N.* liv. p. 18 I have given the formulæ for differential refraction as far as the first order. The expression there expanded is not, however, quite accurate, and, although correct to the second order, will not do beyond that order. If O be the centre of the plate, Ox, Oy the axes, and S, Z the projections on the plate of a star and the zenith respectively, then the effect of refraction is

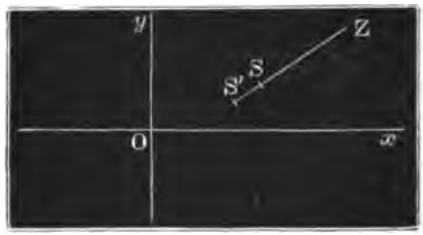


FIG. 1.

to displace S to S′ in the line S Z. So far this is rigidly accurate, since the great circle through the star and the zenith in which the refraction displacement takes place projects into the straight line S Z. But it is assumed in the paper above quoted that S S′ is proportional to tangent zenith distance, which is not quite accurate; in fact, S S′ is assumed equal to the arc of the sphere of which it is the projection; and this is only true to the second order of small quantities, *i.e.* when S is near O. We proceed to deduce the accurate formulæ.

3. Let (X, Y) be coordinates of Z; (x, y) of S; C the centre of the sphere; so that

$$x = \tan \mathrm{SCO} \,.\, \cos \mathrm{SO}x, \qquad y = \tan \mathrm{SCO} \,.\, \sin \mathrm{SO}x$$
$$\mathrm{X} = \tan \mathrm{ZCO} \,.\, \cos \mathrm{ZO}x, \qquad \mathrm{Y} = \tan \mathrm{ZCO} \,.\, \sin \mathrm{ZO}x.$$

Then the direction cosines of the line C S referred to rectangular axes at C are proportional to x, y, 1; and of C Z to X, Y, 1. Hence

$$\cos \mathrm{SCZ} = \frac{1 + x\mathrm{X} + y\mathrm{Y}}{\sqrt{(1 + x^2 + y^2)(1 + \mathrm{X}^2 + \mathrm{Y}^2)}},$$

whence we obtain

$$\tan \mathrm{SCZ} = \pm \frac{\sqrt{(x - \mathrm{X})^2 + (y - \mathrm{Y})^2 + (x\mathrm{Y} - y\mathrm{X})^2}}{1 + x\mathrm{X} + y\mathrm{Y}}.$$

Now the coordinates of S′ may be written

$$x+t(x-X), \qquad y+t(y-Y)$$

since it lies on the straight line S Z. Hence

$$\tan SCS' = \pm \frac{t\sqrt{(x-X)^2+(y-Y)^2+(xY-yX)^2}}{1+x^2+y^2+tx(x-X)+ty(y-Y)}.$$

And

$$\tan SCS' = \mu \tan SCZ,$$

where μ is the constant of refraction, Thus :

$$\pm t(1+xX+yY) = \mu\{1+x^2+y^2+tx(x-X)+ty(y-Y)\}.$$

Since the stars are displaced *towards* the zenith it is clear that the lower sign must be used if μ be taken positive. Hence

$$t = -\mu \cdot \frac{1+x^2+y^2}{1+xX+yY+\mu\{x(x-X)+y(y-Y)\}}$$

and the refractions in x and y are $t\ (x-X)$ and $t\ (y-Y)$ respectively.

In obtaining these results we have made no approximation beyond that of taking the refraction equal to its tangent, which is true to the second order of refraction.

4. We may now expand these expressions in powers of x and y. But before doing so we may reject the term in the denominator multiplied by μ. All the quantities being expressed in circular measure we have approximately

$$\mu = 1/3600 = \cdot 00028$$
$$\mu^2 = \cdot 00000008.$$

The effect of the denominator $P+\mu Q$ is to multiply the numerator by $\left(1-\mu\frac{Q}{P}\right)\frac{1}{P}$. Now x^2 and y^2 are small quantities ; if a star be 10° from the centre of the plate, which may be adopted as a superior limit for most photographs x^2+y^2 is about 0·03. Thus the largest terms introduced into the coordinates of S′ by μQ may be taken equal to

$$+\mu^2 Q(X-x)/P^2.$$

Again it is only at great zenith distances where X and Y are large that such terms can be sensible. Hence we may neglect x and y in comparison with X and Y. Thus :

$$Q = -(Xx+Yy) \text{ and } P = Xx+Yy+1.$$

For simplicity suppose $Y=0$, so that the axis of x is directed towards the zenith. Then the largest term of this kind under consideration is

$$\mu^2 X \cdot Q/P^2 = \mu^2 X^2 \cdot x/(1+Xx)^2.$$

Suppose the star 10° from the centre as before, so that $\alpha = \tan 10°$. and let us put this term equal to 0″·025, or in circular measure $\frac{\pi}{180\times 60\times 60\times 40}$. Then

$$\frac{\pi}{180\times 60\times 2400} = \mu^2 X^2 \cdot \frac{\pi}{18} \cdot /\left(1+\frac{1}{6}X\right)^2$$

or taking the square root

$$\frac{1}{1200} = \frac{1}{3600} X \Big/ \left(1+\frac{1}{6}X\right)$$

or

$$3\left(1+\frac{1}{6}X\right) = X.$$

Thus $X=6$, which corresponds to a zenith distance of 80° 32′. The term is clearly very small in all cases likely to occur in practice. Hence we may omit the term in the denominator multiplied by μ and write

$$t = -\mu \cdot \frac{1+x^2+y^2}{1+\alpha X+yY}$$

with the refractions in x and y

$$\Delta x = (X-\alpha)t, \qquad \Delta y = (Y-y)t$$

$$\therefore \frac{\Delta x}{\mu} = X$$
$$-x(1+X^2)$$
$$+Xx^2(2+X^2)+Xy^2$$
$$-x^3(1+X^2)^2-xy^2(1+X^2)$$
$$+\&c.$$

Since X must be greater than unity to make the higher orders sensible, the largest term of the second order is clearly X^3x^2, and of the third order X^4x^3.

In $\frac{1}{\mu}\Delta y$ there are no terms of the second and third orders comparable with these. The series will not be convergent if Xx is equal to or exceeds unity; but this would mean that the lower edge of the plate is below the horizon, which does not occur in practice. If, however, the plate is near the horizon, it is clear that the convergence is slow, and the expansion in series is not suitable; but the expressions are so simple that special cases can easily be considered individually. There is no need to go into wearisome detail here.

7. We may derive these expressions in a different manner, which has some interesting features. If we project upon the

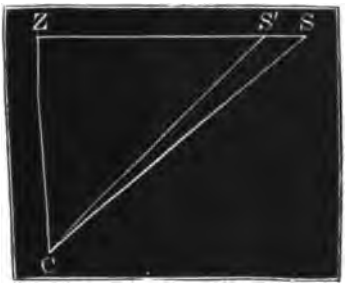


FIG. 2.

tangent-plane at the zenith, and S (fig. 2) be displaced to S′, C being the centre of the sphere and Z the zenith, we have

$$\theta = \angle \mathrm{SCS}' = \mu \tan \mathrm{ZD} = \mu \,.\, \mathrm{SZ} = \mu \,.\, r,$$

say ; and

$$r + \Delta r = \mathrm{ZS}' = \tan (\mathrm{ZCS} - \theta)$$
$$= \frac{r - \mu r}{1 + \mu r^2}.$$

Thus

$$\Delta r = \frac{-\mu r(1 + r^2)}{1 + \mu r^2}.$$

Let (u, v) be the coordinates of S on the tangent-plane at Z. Then $r^2 = u^2 + v^2$ and

$$\mathrm{CS}^2 = 1 + u^2 + v^2,$$

and

$$\Delta u = -\mathrm{SS}' \,.\, \frac{u}{\mathrm{ZS}} = -\mu u \,.\, \frac{1 + u^2 + v^2}{1 + \mu(u^2 + v^2)} = -\rho u, \text{ say}$$

$$\Delta v = -\mathrm{SS}' \,.\, \frac{v}{\mathrm{ZS}} = -\mu v \,.\, \frac{1 + u^2 + v^2}{1 + \mu(u^2 + v^2)} = -\rho v.$$

Now x and y are connected with u and v by relations of the form

$$x = \frac{au + bv + c}{1 - ku - lv}, \qquad y = \frac{du + ev + f}{1 - ku - lv},$$

where $a, b, c \ldots$ are constants (see *Monthly Notices*, vol. liv. p. 11). Thus

$$x + \Delta x = \frac{au + bv + c - \rho(au + bv)}{1 - ku - lv + \rho(ku + lv)},$$

with a similar equation for $y + \Delta y$. Multiply up and use the value of x in terms of u and v to cancel equivalent terms.

Thus

$$\Delta x\{1-ku-lv+\rho(ku+lv)\} = -\rho\{au+bv+x(ku+lv)\}$$
$$=\rho(c-x)$$

or on substituting

$$\rho = \frac{\mu(1+u^2+v^2)}{1+\mu(u^2+v^2)},$$

and simplifying we get

$$\Delta x = +\frac{\mu(c-x)(1+u^2+v^2)}{1-ku-lv+\mu\{(u^2+v^2)+ku+lv\}}.$$

8. There are relations between the coefficients a, b, c, &c., which may be obtained as follows. Let Z, O be the origins of the two systems of coordinates, S a star. Let the initial lines

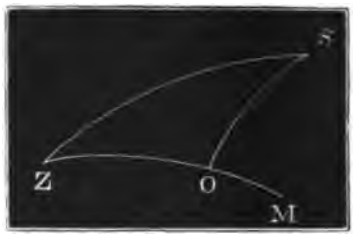


Fig. 3.

make angles α and β respectively with the line ZO; and let $ZO = \phi$. Then

$$u = \tan ZS \cos (SZO+\alpha), \qquad v = \tan ZS \sin (SZO+\alpha)$$
$$x = \tan SO \cos (SOM+\beta), \qquad v = \tan SO \sin (SOM+\beta).$$

Now

$$\sin ZO \sin ZS \cos SZO = \cos SO - \cos SZ \cos ZO$$
$$= \cos SO\,(1-\cos^2 ZO) + \sin SO \sin ZO \cos ZO \cos SOM$$

Thus

$$\sin ZS \cos SZO = \cos SO \sin ZO + \cos ZO \sin SO \cos SOM$$

And

$$\sin ZS \sin SZO = \sin SO \sin SOM.$$

Also

$$\cos ZS = \cos SO \cos ZO - \sin SO \sin ZO \cos SOM.$$

Dividing the two previous equations by this, we get expressions for tan ZS cos SZO and tan ZS sin SZO; *i.e.* for $u\cos\alpha+v\sin\alpha$, and $-u\sin\alpha+v\cos\alpha$. The expressions are fractions the

numerators and denominators of which may each be divided by cos SO : cos ZO ; and then $x\cos\beta+y\sin\beta$ and $-x\sin\beta+y\cos\beta$ may be substituted for tan SO cos SOM and tan SO sin SOM. We then obtain

$$u\cos\alpha+v\sin\alpha=\frac{\tan\phi+x\cos\beta+y\sin\beta}{1-\tan\phi\,(x\cos\beta+y\sin\beta)},$$

$$-u\sin\alpha+v\cos\alpha=\frac{\{-x\sin\beta+y\cos\beta\}\sec\phi}{1-\tan\phi\,(x\cos\beta+y\sin\beta)},$$

and similarly

$$x\cos\beta+y\sin\beta=\frac{u\cos\alpha+v\sin\alpha-\tan\phi}{1+\tan\phi(u\cos\alpha+v\sin\alpha)},$$

$$-x\sin\beta+y\cos\beta=\frac{\{-u\sin\alpha+v\cos\alpha\}\sec\phi}{1+\tan\phi\,(u\cos\alpha+v\sin\alpha)}.$$

9. Thus in the notation of § 7—viz.

$$x=\frac{au+bv+c}{1-ku-lv},\qquad y=\frac{du+ev+f}{1-ku-lv}$$

we have

$$a=\cos\alpha\cos\beta+\sin\alpha\sin\beta\sec\phi$$
$$b=\sin\alpha\cos\beta-\cos\alpha\sin\beta\sec\phi$$
$$c=-\tan\phi\cos\beta$$
$$d=\cos\alpha\sin\beta-\sin\alpha\cos\beta\sec\phi$$
$$e=\sin\alpha\sin\beta+\cos\alpha\cos\beta\sec\phi$$
$$f=-\tan\phi\sin\beta$$
$$k=-\tan\phi\cos\alpha$$
$$l=-\tan\phi\sin\alpha.$$

Further, we remark that the quantities (X, Y) being the values of x and y when $u=0$ and $v=0$ are

$$X=c=-\tan\phi\cos\beta,\qquad Y=f=-\tan\phi\sin\beta.$$

10. For the refraction we want the expressions $1+u^2+v^2$ and $1-ku-lv$ in terms of x and y. Squaring the expressions for $u\cos\alpha+v\sin\alpha$ and $-u\sin\alpha+v\cos\alpha$, and adding we get u^2+v^2, and to this we have to add unity. Perform the operation thus. Put for a moment

$$\xi=x\cos\beta+y\sin\beta,\qquad \eta=-x\sin\beta+y\cos\beta$$

and note that

$$\xi^2+\eta^2=x^2+y^2$$

Then

$$1+(u\cos\alpha+v\sin\alpha)^2=1+\frac{\tan^2\phi+2\xi\tan\phi+\xi^2}{1-2\xi\tan\phi+\xi^2\tan^2\phi}$$

$$=\frac{(1+\xi^2)\sec^2\phi}{(1-\xi\tan\phi)^2}$$

$$(-u\sin\alpha+v\cos\alpha)^2=\frac{\eta^2\sec^2\phi}{(1-\xi\tan\phi)^2}$$

Thus

$$1+u^2+v^2=\frac{(1+x^2+y^2)\sec^2\phi}{(1-\xi\tan\phi)^2}$$

$$=\frac{(1+x^2+y^2)(1+X^2+Y^2)}{(1+xX+yY)^2}$$

from the expressions for X and Y given in the last paragraph.

Again

$$1-ku-lv=1+\tan\phi(u\cos\alpha+v\sin\alpha)$$

$$=1+\frac{\tan^2\phi+(x\cos\beta+y\sin\beta)\tan\phi}{1-\tan\phi(x\cos\beta+y\sin\beta)}$$

$$=\frac{1+X^2+Y^2}{1+xX+yY}$$

11. Substituting these now in the expression of § 7—viz.

$$\Delta x=-\frac{\mu(c-x)(1+u^2+v^2)}{1-ku-lv+\mu\{u^2+v^2+ku+lv\}}$$

and in the first instance neglecting the term multiplied by μ in the denominator we get

$$\Delta x=\mu\frac{(X-x)(1+x^2+y^2)}{1+Xx+Yy}$$

as in § 5. The neglected term is easily seen to be identical with that in § 3 and § 4 on remarking that the coefficient of μ is

$$u^2+v^2+ku+lv\equiv(1+u^2+v^2)-(1-ku-lv)$$

$$=\frac{(1+X^2+Y^2)\{x(x-X)+y(y-Y)\}}{(1+xX+yY)^2}.$$

12. The same algebraical expression applies when instead of the mean coordinates of the star we use the apparent coordinates, modifying the value of μ accordingly.

University Observatory, Oxford:
1897 *January* 7.

The Heliographic Coordinates of Sun-spots and Faculæ on the Stonyhurst Drawings. By the Rev. A. L. Cortie, S.J.

The photographic method of registering the positions of sun-spots and faculæ, and their micrometrical measurement from the photographs as practised at Greenwich, is doubtless the most perfect of those in use. Taking the positions as reduced, and published in the annual volumes of "Spectroscopic and Photographic Results" as standard, it will be useful to compare with them some positions which have been obtained from the Stonyhurst drawings by the use of a set of orthographic projections of the parallels of latitude and meridians of longitude, and to explain the method by which these positions have been obtained. For the process of measurement by means of projections is most simple and expeditious, and, moreover, is susceptible of considerable accuracy. The drawings themselves are made by projecting the image of the Sun on to a sketching-board, the diameter of the image being $10\frac{1}{2}$ inches. It is only necessary to rule one horizontal diameter of the circle prepared to receive the solar image in order to adjust the drawing to the apparent north point. This is effected by causing a spot to run truly along this diameter by means of the slow-motion rods of the telescope. It is better to choose a small spot for this purpose.

As the heliographic latitude of the centre of the Sun's disc varies between $\pm 7°\ 15'$, eight orthographic projections of the meridians and parallels, corresponding to the fifteen positions of the pole ± 0 to $\pm 7°$, were drawn with great care and exactness by Mr. William McKeon. They were then traced on glazed linen, so as to permit of their being placed over a drawing for measurement, all the details on the drawings being easily seen through the projection. Moreover they are very durable, and, as experience has proved, not liable to shrink, thus being an excellent substitute for costly projections ruled on glass.

Each of the projections has, moreover, a scale of degrees from 0 to $\pm 30°$, ruled along its limbs north and south of the projection of the Sun's equator, to enable the disc to be adjusted for the varying position of the angle of inclination of the Sun's polar axis, this variation being within the limits $\pm 26°{\cdot}5$ from the N. point. With these discs the "Ephemeris for Physical Observations of the Sun," published yearly in the *Companion to the Observatory*, must be used, values of P, D, and L being easily interpolated for the day and time of observation.

The use of the projections will be best illustrated by an example. To find the heliographic coordinates of a sun-spot drawn in the S.F. quadrant of the Sun at $9^h\ 37^m$ G.M.T. on 1893 Aug. 9. For this date and time $P = +14°{\cdot}33$, $D = +6°{\cdot}46$, $L = 266°{\cdot}56$. Measure the apparent latitude and longitude by means of the projection for $D = \pm 6°$, adjusting it with reference to the horizontal diameter ruled on the picture to the reading

+14°·3. The readings are for latitude −16°·8, for longitude −53°·5. If the spot should be large, take the readings of its edges and deduce the mean. Since the meridians and parallels are drawn at intervals of 10°, in estimating degrees and parts of a degree it will be necessary to use subsidiary scales, allowing for the gradual foreshortening as the limbs are approached. These can be ruled on slips of paper as required.

The projection readings must now be corrected. The latitude of the centre of the disc at the time of observation was +6°·46, and we have used the projection corresponding to latitude +6°. If the spot had been situated on the central meridian it is evident that its latitude being south the correction to be applied would have been +0°·46. But it is distant 53°·5 from the central meridian. The distance between the projections of the equators on two successive discs is evidently 1° on the central meridian and 0° at the points to which they converge on or in the immediate neighbourhood of the limb. At intermediate meridians it is successively and proportionally less than 1°, reckoning from the central meridian. The factor to be applied is the natural cosine of its angular distance from the central meridian, and the correction to the apparent latitude depends on the apparent longitude. In applying this correction it is only necessary to employ the first two figures of the value of the natural cosine. In the present instance, therefore, +·46×·59 is the correction to be applied. Hence the true latitude of the spot is −16°·5 S. We stated that L for the date and time of the drawing was 266°·56. This value has been thus derived: At noon on August 9 L for the central meridian was 265°·25, but the outline of the spot was traced at $9^h\ 37^m$, or $2^h\ 23^m$ before noon; and although the difference in longitude of the central meridian for an interval of twenty-four hours varies with the time of the year, yet it is sufficiently accurate to reckon the mean difference in longitude for this period as 13°·22. Hence the differences for hours and minutes can easily be deduced. For $2^h\ 23^m$ the correction to be applied is +1°·31. Hence L at the time of the drawing was 266°·56, and the true longitude of the spot becomes 266°·56 −53°·5=213°·1. The Greenwich results for the same spot are lat. −16°·1, long. 213°·1. As the projections are made for every whole degree, the error, either in the parallels or the meridians of any projection used, ought not to exceed what would correspond to a difference of half a degree of polar tilt, since each whole degree projection is used only for dates corresponding to the nearest half degree at either side of it. This error is reduced by the use of the table of natural cosines as explained. The error of the meridians due to a difference of half a degree of tilt is in the spot zones about two-tenths of a degree as a maximum. This error also can be eliminated by measuring the longitude a second time by means of a projection corresponding to half a degree polar tilt in the reverse sense and taking the mean of the two readings. In this manner the error in longitude can be reduced to about 0°·1.

As pointed out in the "Researches on Solar Physics," by W. De la Rue, B. Stewart, and B. Loewy (*Phil. Trans.* 1869, p. 10), the measured distance of a spot from the centre of a drawing is greater than its true angular distance from the central meridian of the Sun. In using orthographic projections for deducing the positions of the sun-spots an error due to this difference will always enter into the measurements. But if a spot is followed across the disc the errors on both sides of the central meridian, being of opposite sign, will neutralise each other in determining the mean longitude of the spot. But this is not the case for the latitudes, which ought therefore to be always greater than the true latitude. The maximum value of this error is between 0°·2 and 0°·3 for projections of 10½ inches diameter. Hence in using projections such as those described the longitudes should be much nearer the Greenwich standard positions than the latitudes, and for the latter the maximum cumulative error from all causes ought not to exceed 0°·4. Having at hand 82 positions of sun-spots for the year 1889, originally measured for a different object, we have compared them with the Greenwich positions for the same spots on the same dates. Of these measures 5 of the longitude and 9 of the latitude have been rejected as anomalous, either because the spots were very near the limb where measures are made with difficulty, or because they were changing their positions rapidly. Of the remaining 77 positions in longitude 3 differ 0°·6, 6 differ 0°·5, and 5 differ 0°·4 from the Greenwich positions, the remaining 63 varying between the limits 0° to 0°·3. Of the 73 positions in latitude used in the comparison 5 differ 0°·7, 5 differ 0°·6, 4 differ 0°·5, and 4 differ 0°·4 from the Greenwich positions, while 55 are within the 0°·3 limit. If, however, we take the mean positions of the groups the accordance is much closer, as the following table shows. For the omitted groups from the table either we have no positions from the drawings, or in two cases, groups 2099 and 2100, the results are vitiated by the anomalous positions alluded to above.

No. of Group.	Greenwich Mean. Long.	Lat.	Stonyhurst Mean. Long.	Lat.	Difference G—S. Long.	Lat.	No. of Comp.
	°	°	°	°	°	°	
2083 (*a*)	318·64	− 7·89	318·54	− 8·11	+0·10	−0·22	8
2085	311·53	+ 5·88	311·53	+ 5·75	0	+0·13	4
2086	315·10	+ 5·10	315·20	+ 4·72	−0·10	+0·38	5
2088	217·43	− 1·55	217·43	− 1·83	0	−0·28	4
2090 (*a*)	31·10	− 5·42	31·08	− 5·60	+0·02	−0·18	11
2092	36·31	− 7·91	36·30	− 8·32	+0·01	−0·41	9
2094 (*a*)	343·55	−23·40	343·65	−23·45	−0·10	−0·05	2
2097 (*a*)	163·78	−20·35	163·88	−20·58	−0·10	−0·23	6
2097 (*b*)	155·43	−21·60	155·53	−21·65	−0·10	−0·05	4
2103	151·85	−20·65	151·73	−21·12	+0·12	−0·47	6
2110	101·13	−26·53	101·03	−26·63	+0·10	−0·10	3

It is to be understood, of course, that the drawings can also be measured and reduced according to the methods detailed in Carington's researches on solar physics, our present object being to show how closely the simple method of projection measurement approximates to those that are more accurate. The appended verification of the exactness with which the projections have been drawn, and a method of measurement deduced from them which is independent of their use, is due to the Rev. James Cullen, of this college.

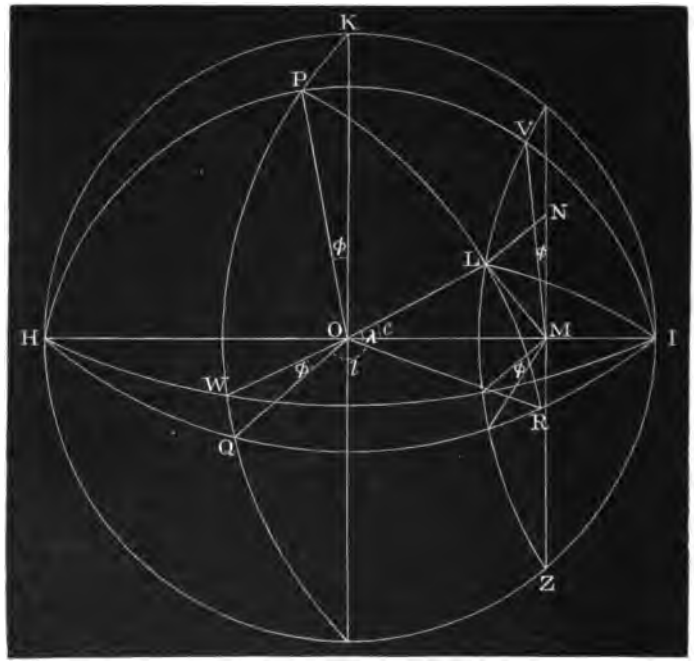


FIG. 1.

1. The discs have been verified in the following manner :— In fig. 1 let P be the pole of the Sun, HQRI his equator, HWI the GC of which K is the pole. If, then, L is a spot, its co-ordinates (heliographic) are QR and RL. It is clear that as P moves in the meridian KPWQ, L will move in the small circle VLZ, the radius of which is LM=OL sin $c=r$ sin c (r=radius of sphere). But c=LI, the hypotenuse of the right-angled triangle LIR ; LR $=\lambda$ (the latitude) ; RI=90$-l$ (l being the longitude).

$$\therefore \cos c = \cos \lambda \sin l.$$

Hence

$$\mathrm{LM} = r\,(1 - \cos^2 \lambda \sin^2 l)^{\frac{1}{2}},$$

and if $\angle \mathrm{LIV} = \theta$

$$\mathrm{MN} = \mathrm{LM} \cos(\theta + \phi).$$

Now $\theta = \mathrm{I}$, the angle of the triangle PLI; $\mathrm{PL} = 90° - \lambda$; $\mathrm{PI} = 90°$; and

$$\mathrm{LI} = c = \cos^{-1}\{\cos \lambda \sin l\};$$

whence applying the formula

$$\cos \mathrm{A} = (\cos a - \cos b \cos c)/\sin b \sin c,$$

where $\mathrm{A} = \theta$, $a = \mathrm{PL}$, $b = 90°$, we get

$$\cos \theta = \sin \lambda / (1 - \cos^2 \lambda \sin^2 l)^{\frac{1}{2}}.$$

Therefore substituting for θ in $\mathrm{MN} = \mathrm{LM} \cos(\theta + \phi)$, we have

$$\mathrm{MN} = y = r(\cos \phi \sin l - \sin \phi \cos \lambda \cos l) \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\mathrm{OM} = x = r \cos c = r \cos \lambda \sin l \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

The curves giving the meridians and parallels of latitude are found by making $l = a$ (a constant) and eliminating λ between (1) and (2) or making $\lambda = \beta$ and eliminating l.

Knowing ϕ, λ, and l, we can find the ordinates and abscissæ of any of the points of intersection of the parallels of latitude and meridians of longitude on the discs. This has been applied to the Stonyhurst projections, and they were found to be absolutely correct.

2. As stated in the paper, a proportional table was constructed empirically from measurements taken on the discs in order to apply a correction to the latitude due to the apparent longitude of the spot. That this is a table of natural cosines can be thus shown.

For a projection ϕ_1, say, we have from (1)

$$y_1 = r(\cos \phi_1 \sin \lambda - \sin \phi_1 \cos \lambda \cos l),$$

and similarly for ϕ_2 another projection

$$y_2 = r(\cos \phi_2 \sin \lambda - \sin \phi_2 \cos \lambda \cos l)$$

$$\therefore y_1 - y_2 = r\{(\cos \phi_1 - \cos \phi_2) \sin \lambda - (\sin \phi_1 - \sin \phi_2) \cos \lambda \cos l\}$$

and as ϕ_1 and ϕ_2 always lie between 0° and 8°, $\cos \phi_1$ and $\cos \phi_2$ lie between 1 and ·990; so that $\cos \phi_1 - \cos \phi_2$ never can be greater than ·01, and as two successive projections are generally used, it really becomes $\cos \phi° - \cos(\phi + 1)° = ·001$ (nearly); and as this is multiplied by $\sin \lambda$ (λ being small for spots), we may neglect the first term in the formula. Hence we have

$$y_1 - y_2 = r(\sin \phi_2 - \sin \phi_1) \cos \lambda \cos l,$$

which varies as $\cos l$ as in the case of equators, for when $\lambda = 0$

$$y_1 - y_2 = r(\sin \phi_2 - \sin \phi_1) \cos l$$

by the general formulæ.

Between 0° and 64° on a disc whose radius is 133·35 mm. (or 5¼ in.) an error of 0·1 mm. in the equator cannot cause a greater error than 6′ or 0°·1 in the longitude. But at the limb *one degree* is represented by 0·02 mm.

3. From the consideration of the fundamental equations (1) and (2) a method of measurement of the position of sun-spots can be derived directly from the drawings without the use of any discs. From the *Companion to the Observatory* the position-angle of the north pole of the Sun, &c., can be derived for any day. Let NWSE (fig. 2) represent the picture, draw the polar

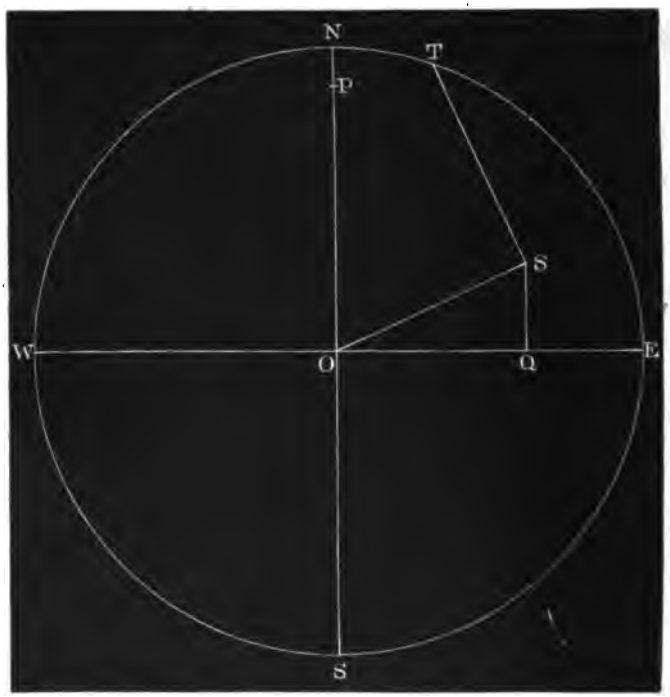


FIG. 2.

and equatorial diameters NS and WE. Then from (1) and (2) we get

$$\cos l = (r^2 \cos^2 \lambda - x^2)^{\frac{1}{2}}/r \cos \lambda,$$

and

$$(y - r \cos \phi \sin \lambda)^2 = \sin^2 \phi \, (r^2 \cos^2 \lambda - x^2)$$

$$\therefore y^2 - 2ry \cos \phi \sin \lambda + r^2 \cos^2 \phi \sin^2 \lambda - r^2 \sin^2 \phi \cos^2 \lambda + x^2 \sin^2 \phi = 0;$$

i.e.

$$r^2 \sin^2 \lambda - 2ry \cos \phi \sin \lambda + x^2 \sin^2 \phi - r^2 \sin^2 \phi^2 + y^2 = 0,$$

or

$$(r \sin \lambda - y \cos \phi)^2 = \sin^2 \phi \{r^2 - (x^2 + y^2)\}$$

$$\therefore \sin \lambda = [y \cos \phi + \sin \phi \{r^2 - (x^2 + y^2)\}^{\frac{1}{2}}]/r.$$

The positive sign must be taken in extracting the square root, since from (1)

$$\sin \lambda > y \cos \phi / r$$

or

$$> \cos^2 \phi \sin \lambda - \sin \phi \cos \phi \cos \lambda \cos l$$

if λ, ϕ, and l are positive.

In practice the following method will facilitate the evaluation of λ. Let S be the spot; join O and S, draw S T perpendicular to O S; join O and T, and draw S Q perpendicular to O E. Then $OQ = x$ and $SQ = y$; $OT = r$. We have therefore

$$ST^2 = OT^2 - OS^2 = r^2 - (x^2 + y^2).$$

Since

$$OS^2 = x^2 + y^2 \therefore ST = \{r^2 - (x^2 + y^2)\}^{\frac{1}{2}}$$

Hence

$$\sin \lambda = (y \cos \phi + ST \sin \phi)/r \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

and

$$\sin l = x/r \cos \lambda \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

λ being found from (3).

We may write

$$\sin \lambda = y \, . \, \alpha + ST \, . \, \beta,$$

where $\alpha = \cos \phi / r$, and $\beta = \sin \phi / r$, these quantities being determined each day: y is negative if measured southwards, β is negative when ϕ is negative, and λ is S. lat. when $\sin \lambda$ is negative.

A convenient way of making use of this method would be to have a right-angled elbow-ruler graduated along both edges in inches or millimetres. Let the zero point be at the elbow; the reading to the centre of the spot gives the x and the reading at right angles to the centre of the disc, the y. Now place the zero point at the centre of the spot, with one edge passing through the centre of the picture; the reading where the other edge cuts the circle gives us ST, and hence the heliographic coordinates can be easily calculated from equations (3) and (4).

4. In the cases where the correction for refraction is needed a modification of the formulæ given in the Introduction to the Greenwich Spectroscopic and Photographic Results can be employed.

Mercury. By Percival Lowell.

(*Communicated by the Secretaries.*)

The markings on the planet's disc proved at once to be conspicuous. To reduce them to a scale I may say that they were easier to see than all the markings on *Mars* except the most salient ones, such as the so-called Seas. So visible were they at all times—for the air had to be distinctly bad to obliterate them—that observations had not been made more than a day or two, before the rotation period of the planet was patent.

Further communication upon this planet I intend to give later.

Lowell Observatory:
1896 *October* 21.

[In addition to those reproduced, Mr. Lowell sends several prints of drawings of *Mercury*, which have been placed in the Library.—Eds. *M.N.*]

Determination of the Rotation Period and Surface Character of the Planet Venus. By Percival Lowell.

(*Communicated by the Secretaries.*)

The rotation period of *Venus* has hitherto been a matter of doubt. I beg therefore to communicate to the Society the following observations made by me during August, September, and October of this year, which prove that rotation to be performed in the same time as the planet's orbital revolution. I send drawings by me and by my assistant, Mr. Drew. Comparison of the drawings will show their conclusive character, and from them I have been able to construct the accompanying chart.

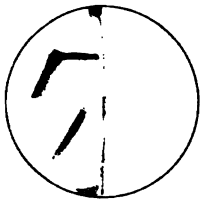
In the construction of the chart I have taken for the zero longitude that longitude which is upon the central meridian as observed from the Sun when the planet is in the line of apsides of its orbit, either at perihelion or at aphelion, such being the most natural origin to adopt.

In orienting the different drawings of the disc the libration in longitude due to the excentricity of the planet's orbit is added to or subtracted from the value resulting from the planet's orbital revolution. In the case of *Venus* the resulting change is very small, never amounting to more than 47′ at its maximum.

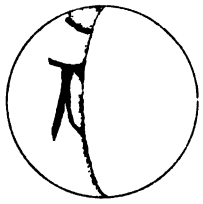
The planet's axis of rotation is substantially perpendicular to the plane of its orbit, as the observations have not yet disclosed any deviation from this position.

In the names for the markings I have selected such as seemed appropriate to the Planet of Love. The markings themselves are

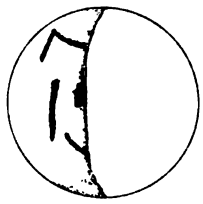
MERCURY, 1896.



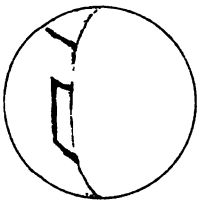
Sep. 14, 2h 52m
λ = 98°



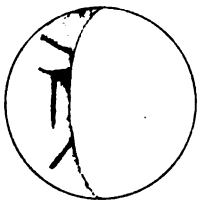
Sep. 19, 5h
λ = 115°



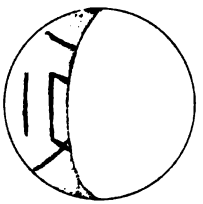
Sep. 23, 3h 12m
λ = 130°



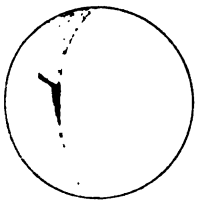
Sep. 23, 3h 30m
λ = 130°



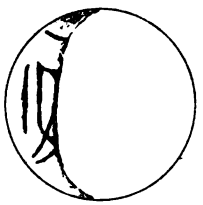
Sep. 23, 4h
λ = 130°



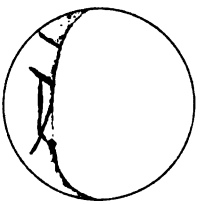
Sep. 23, 4h 42m
λ = 130°



Sep. 25, 2h 13m
λ = 138°



Sep. 26, 3h 22m
λ = 141°



Sep. 26, 3h 56m
λ = 141°

Percival Lowell, del.

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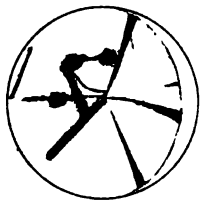
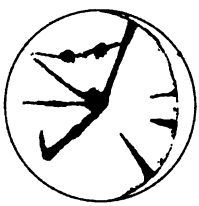
VENUS, 1896.

Oct. 13, 2h 55m to 3h 4m
λ = 37°

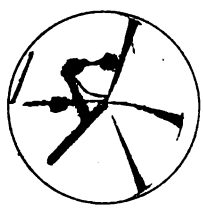


Oct. 14, 1h 59m to 2h 12m
λ = 37°

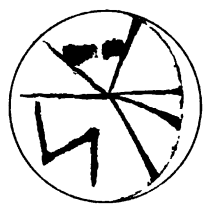
Oct. 14, 3h 13m to 18m
λ = 37°



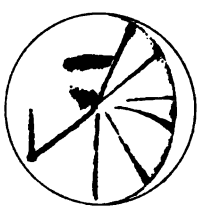
Oct. 14, 3h 50m
λ = 37°



Oct. 15, 0h 5m to 14m
λ = 37°

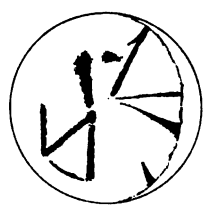


Oct. 15, 1h
λ = 37°



Oct. 15, 2h 10m to 21m
λ = 37°

Oct. 15, 3h 48m to 54m
λ = 37°



Oct. 15, 4h 37m
λ = 37°

Percival Lowell, del.

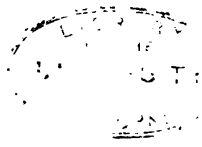
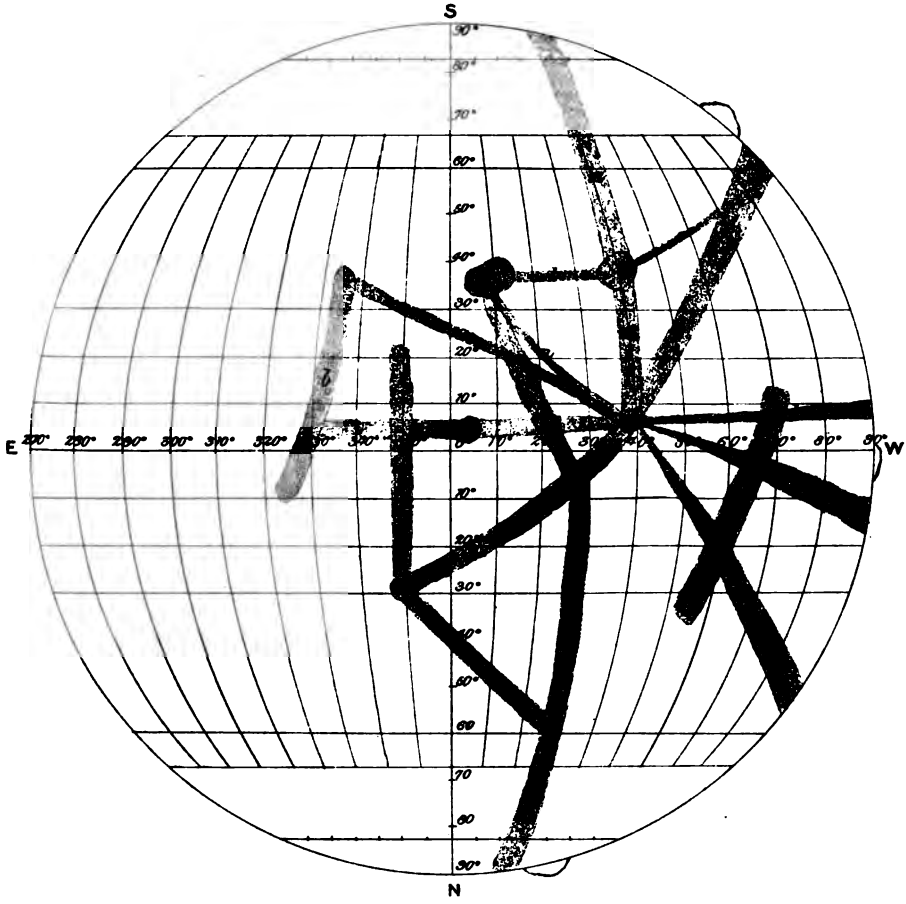


CHART OF VENUS.



Percival Lowell, del.

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long and narrow; but, unlike the finer markings on *Mars*, they have the appearance of being natural, not artificial. They are not only permanent, but permanently visible whenever our own atmospheric conditions are not so poor as to obliterate all detail on the disc. They are thus evidently not cloud-hidden at any time. But the whole disc, dark and light portions alike, is brightened as by a luminous atmosphere. When compared with the appearance of the disc of *Mercury* or of our own Moon, the appearance of the disc of *Venus* is such as to make the presence of a very substantial atmosphere evident. Measures of the polar and equatorial diameters confirm this deduction by disclosing by comparison with *Mercury* a visible twilight arc.

There is no distinctive colour in any part of the planet other than its general brilliant straw-colour hue. The markings, which are of a straw-coloured grey, bear the look of being ground or rock, and it is presumable from this that we see simply barren rock or sand weathered by aeons of exposure to the Sun. The markings are perfectly distinct and unmistakable, and conclusive as to the planet's period of rotation.

There is no certain evidence of any polar caps. Only once have I seen anything which might be so construed, and even that is perfectly explicable by a greater luminosity of the surface at those points. The planet's surface presents as dead an appearance as does that of our own Moon.

Lowell Observatory:
1896 *October* 21.

[In addition to those reproduced, Mr. Lowell sends several prints of drawings of *Venus*, which have been placed in the Library.—Eds. *M.N.*]

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Lowell Observatory:
1896 *October.*

Determination of the Diameter and the Compression of the Planet Mars from Observations with the Repsold Heliometer of the Royal Observatory, Göttingen. By Professor W. Schur.

(*Communicated by the Astronomer Royal.*)

The question of the compression of *Mars* is still open, as the former measures of the equatorial and the polar diameter may be influenced by errors of estimation to which the eye is liable in the measurement of discs in different directions with respect to the vertical line.

But since small reversion prisms are used on the eyepiece of the heliometer, with which the image of a celestial body, *e.g.* the line joining a double star or the diameter of a planetary disc, can be made to appear in any direction with respect to the vertical line, it is possible to get free from these subjective influences.

I have, therefore, awaited the opposition of *Mars* of this year, which is so favourable on account of the high declination of the planet, with great anxiety to observe the equatorial and the polar diameter with the said precautions.

All instrumental errors and the very small correction for defect of illumination according to the ephemeris of Mr. Marth are taken into account.

The diameter of the object-glass is 162 millimetres and the power used 174.

The following are results of four nights, where v and h denote the measurements with apparent vertical and horizontal movements of the images in the field of the eyepiece.

Date.	Mean Time Göttingen.	Areographic latitude.	Measured diameter.	Diameter in mean distance from the Sun.	Mean of v and h.
1896.	h m	°	"	"	"
Dec. 2	11 45	90	16·81v	6·19	6·15
			16·60h	6·11	
		0	17·06v	6·28	6·30
			17·16h	6·32	
		0	17·03h	6·27	6·23
			16·79v	6·18	
		90	16·66h	6·13	6·10
			16·49v	6·07	
11	10 19	90	16·52h	6·14	6·13
			16·45v	6·11	
		0	17·04h	6·33	6·30
			16·85v	6·26	
		0	16·92v	6·29	6·32
			17·09h	6·35	

Date.	Mean Time Göttingen.	Areographic latitude.	Measured diameter.	Diameter in mean distance from the Sun.	Mean of v and h.
1896.	h m	°		″	″
Dec. 11	10 19	90	16·55v	6·15	6·14
			16·47h	6·12	
16	8 2	90	16·18h	6·12	6·10
			16·06v	6·07	
		0	16·44h	6·22	6·11
			16·43v	6·21	
		0	16·44v	6·22	6·21
			16·40h	6·20	
		90	16·11v	6·09	6·09
			16·11h	6·09	
17	9 36	0	16·46h	6·26	6·24
			16·34v	6·21	
		90	16·24h	6·17	6·15
			16·10v	6·12	
		90	16·06v	6·10	6·10
			16·06h	6·10	
		0	16·25v	6·18	6·24
			16·54h	6·29	

December 2 the images, principally in the beginning, were less steady, but on the other days pretty and sharp.

Taking the mean of the numbers in the last column, one gets for the axes of the Martian disc in mean distance from the Sun (log=0·18289).

1896.				
Dec. 2	$2a = 6''\cdot265$	$2b = 6''\cdot125$	$\alpha = \frac{a-b}{a} = \frac{1}{44\cdot7}$	
11	6·310	6·135	$\frac{1}{36\cdot1}$	
16	6·210	6·095	$\frac{1}{54\cdot0}$	
17	6·240	6·125	$\frac{1}{54\cdot3}$	

The mean for the four observing nights gives the compression nearly $= \frac{1}{47}$, and the diameters are—

$$2a = 6''\cdot256 \qquad 2b = 6''\cdot120.$$

Reduced to the distance, Earth-Sun the diameters are—

$$2A = 9''\cdot53 \qquad 2B = 9''\cdot32.$$

From the results of these observations, which in my opinion are perfectly free from any disturbing influence, it seems to be not doubtful that the compression of the planetary disc is nearly $\frac{1}{47}$.

Remarks on the Physical Observations of Jupiter, made at the Adelaide Observatory, 1884–93. By E. P. Sells.

(*Communicated by Sir Charles Todd.*)

Drawings of *Jupiter* were made at the Adelaide Observatory, with the 8-inch Cooke refractor, from 1884 till 1893, with the exception of 1890.

It was early recognised that the utility of the drawings would be much increased if the two following conditions were complied with:—

(1) The drawings to be arranged for publication, not in the usual way of separate discs for each drawing, but on some cylindrical form of projection, allowing of easy comparison between the results obtained on different nights.

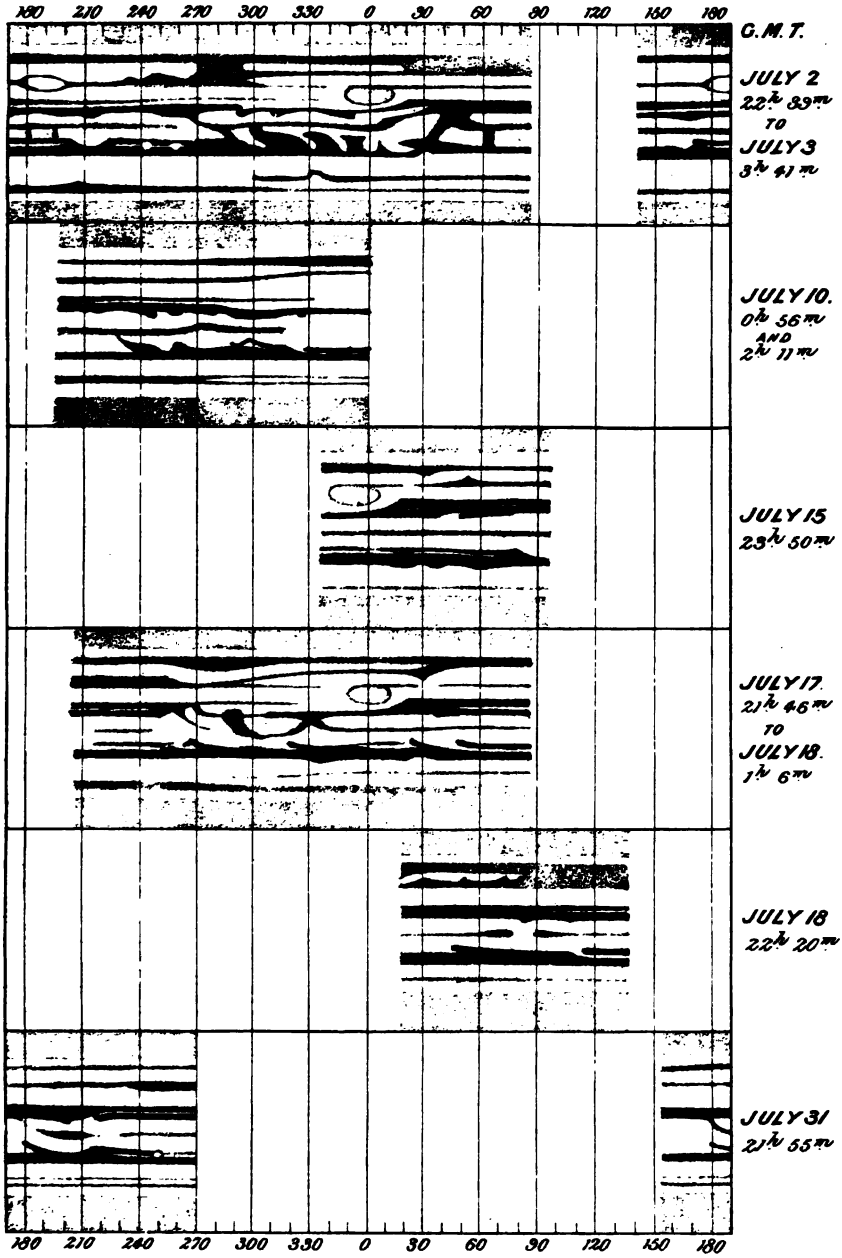
(2) As many drawings as possible to be taken on each night of observation, four or five drawings on one night being preferable to one drawing on each of four or five nights.

With regard to condition (1), the form of projection chosen was the orthographic, being the most natural projection for *Jupiter*. The drawings at the telescope were made on blank elliptical discs, as is usual, and were afterwards plotted on a chart having its polar diameter equal to that of the elliptical disc, the longitudes being taken from Marth's "Ephemeris," System II.

It will be seen from the accompanying planisphere that each night of observation has a chart to itself, and the different charts are arranged one below the other, and are separated from each other by only a thin black line, thus allowing of easy comparison *inter se*. The number of charts on a sheet is of necessity limited by the size of the publication of which they form a part, but it is, of course, an advantage to have as many charts as possible on each sheet. No latitude parallels are shown, as they would only confuse the eye, but meridians are given to every 30°, and along the top and bottom of the sheet to every 10°.

With regard to condition (2), drawings were made as nearly as possible at intervals of fifty minutes, answering to a difference of 30°·2 Jovian longitude. Attempts were made to secure sets of drawings showing the whole of *Jupiter's* surface during one revolution of the planet, but in no case was this satisfactorily accomplished, although on 1889 June 23–24 G.M.T. nine drawings were secured, of which the first and last slightly overlapped, so that on the planisphere the whole disc is delineated. On all occasions, however, observations were interrupted either by cloud or by a south-easterly breeze, the lightest breath of air from that quarter sufficing to destroy the quality of the definition, so that the true forms of the markings could not be made out, and all delicate detail vanished. Great attention has been paid at Adelaide to giving the markings their true forms (as they

JUPITER, 1889.



E. P. Sells, del.

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appeared to the observer) and definite, but not necessarily hard, outlines have been drawn whenever possible.

In all, 217 drawings have been plotted on the charts, ranging in date from 1884 February 25 to 1893 December 11.

At no time have the Polar and Temperate Regions shown much detail, but this is, of course, partly due to the foreshortened view that is obtained of those portions of the planet. The outburst of small dark spots in 1891 on the southern edge of the North Temperate Belt was remarkable, especially when taken in conjunction with the somewhat similar outburst in 1880 and 1881, but this has been sufficiently commented on by other observers. After the outburst had subsided, and during the apparitions of the planet in 1892 and 1893, this belt had become very dark, and towards the end of 1893 was the darkest marking on the planet. In South Temperate Regions perhaps the chief feature has been the trains of small round white spots that sometimes make their appearance, of which there are numerous instances among our drawings. Also noticeable are the short dark belts that form in about latitude 25° S., of which the most conspicuous examples are the two that were visible in 1891, one of them being of a very dark reddish colour. An interesting feature was the appearance of a small dusky spot in 1884, 1886, and 1889, interrupting the line of the South Temperate Belt. The spots may not have been identically the same, but were very similar in appearance. Two drawings, showing the spot as it appeared in 1884 and 1889, respectively, accompany this paper. In 1884 it was seen on March 20 (long. 144°·5) and April 6 (long. 128°·9), and then appeared as a small circular dusky spot with a clear space all round it, interrupting the line of the narrow Belt 6 (see *Monthly Notices* for April 1891, p. 404), while the south polar shading, separated from Belt 6 by a very narrow white space, had its northern contour hollowed out immediately south of the spot, and also had a darker degree of shading at the same place.

In 1886 a pear-shaped spot was seen in the same latitude. Again it interrupted the line of Belt 6, and again the south polar shading had a darker shade immediately south of the spot; but there was no dip southwards of the edge of the shading as in 1884, perhaps because the white space was much broader between the shading and Belt 6. The spot was noticed on February 3 (long. 73°), February 8, and February 22, but after that was not seen again until 1889, when a similar spot made its appearance in the same latitude. In 1889 the spot and Belt 6 were darker and broader than formerly, and the belt appeared joined on to a band of shading to the south. The longitude of the spot 1889 June 25 at $0^h\ 24^m$ G.M.T. was 141°·2.

The equatorial regions during some apparitions of the planet showed a large amount of detail, but during others the markings were few. There have always been, during the period 1884–1893 the two chief belts, the North and South Equatorial Belts, though in 1884 the North Equatorial Belt was broken up along

part of its length into short disconnected belts. In 1885 the belt was continuous and had become far more conspicuous, while in 1886 it showed a fair amount of structural detail. Only a few drawings were taken here in 1887 and 1888, but the belt still showed a quantity of detail, as was also the case in 1889. No observations were taken in 1890, but in 1891 the belt had a more regular outline, and had become very narrow and dark along part of its course. It appeared to consist of two different layers of matter, one very dark and narrow, and the other fainter and broader, the dark, narrow layer coming to a clearly defined end within the lighter broad layer.

The two dark spots on the northern component of the double portion of the belt, in longs. 220°–255°, were seen and drawn on five nights.

In 1892 and 1893 the belt had become still narrower, and showed very little detail, but towards the end of 1893 it was getting broader again, and was double for part of its length.

The South Equatorial Belt has always been a conspicuous marking. It is generally, but not always, divided longitudinally by a white streak, while sometimes a white streak will cross it at a considerable angle. Perhaps the most usual appearance of this belt, as seen at Adelaide, has been that of a comparatively lightly shaded belt, divided longitudinally by a white streak, and having superposed upon its northern component other dark belts, short in length, and frequently with a club-shaped termination projecting into the bright equatorial zone, and forming the bases from which spring the festoons and other shadings that appear on that zone.

When observations were begun in 1884 the Great Bay in the southern edge of the South Equatorial Belt, north of the Great Red Spot, was a conspicuous feature, and was symmetrically shaped, the angular shoulders on either side being similar to one another. On 1884 April 20 at $20^h\ 37^m$ G.M.T. the *preceding* angle of the Great Bay was found to be exceptionally sharp and well defined, and appeared of a deep blood-red colour, fading off towards the preceding limb. The colour was most marked. In 1885 this angular shoulder on the *preceding* side of the Great Bay had disappeared, except that a narrow faint line was sometimes visible in the position of its southern edge, nor did it appear again up to the end of 1893.

In 1892 and 1893 the belt showed very little detail, and there was a striking absence of markings on the bright equatorial zone, all the equatorial regions of the planet appearing to be in a state of comparative quiescence.

[In addition to the chart reproduced, Mr. Sells also sent a chart for 1888, which is placed in the Library.]

Note on the Magnitude of η Argûs, 1896. By R. T. A. Innes.

(Communicated by Dr. Gill, H.M. Astronomer.)

Four determinations of the brightness of this star were made here in 1896, viz.—

	Mag.
Apr. 26	7·6
May 17	7·5
June 28	7·6 orange yellow
July 13	7·6
Means 1896·43	7·58

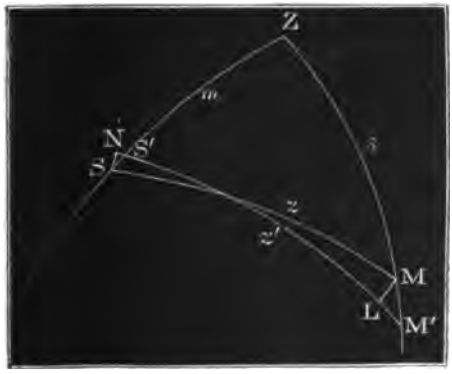
The telescope used was the 7-inch equatorial, and the comparison stars and magnitudes are those given for that purpose in the *Uranometria Argentina.*

The magnitude of *η Argûs* was also determined here in 1886 March (see *M.N. R.A.S.* vol. xlvi. page 340) by Mr. W. H. Finlay, on which occasion it was found to be 7·6 mag., the same comparison stars being used.

Royal Observatory, Cape of Good Hope:
1896 *December* 16.

A Method of Clearing a Lunar Distance. By F. C. Penrose.

Various methods have been proposed for facilitating the operation in nautical astronomy of clearing the lunar distance. One was brought before the Society in 1884 by Mr. John Merrifield, which is printed in the *Monthly Notices* for April of that year. The plan I here venture to propose has thus much in common with that above mentioned, viz. that it deals chiefly with the small triangles which result from parallax and refraction, but it is dissimilar in all other respects.



The advantage looked for is that, whilst all desirable accuracy is obtained, it can be worked with logarithms restricted to four places, and thereby lightens the labour of calculation, and to some degree also the chance of errors in computation.

Let Z be the zenith, M′ and S′ the apparent, and M and S the true places of the Moon and Sun or star, and z' and z the apparent and true distance respectively, and let the sides of the small triangles about M and S be named—MM′, δs, M′L δz and SS′ and SN δm and $\delta z_{,,}$ respectively. It can easily be shown that when these triangles are very small *

$$\delta z = \delta s \left(\frac{\cos m \,.\, \sin s - \sin m \,.\, \cos s \,.\, \cos Z}{\sin z} \right)$$

and the same, *mutatis mutandis*, applies to $\delta z_{,,}$. The triangle connected with S will almost always be small enough, but that at M, when great accuracy is required, will generally need a small correction, but one that is very easily applied.

Taking an example from *Raper's Navigation* (p. 289 of 9th edit.)—

Apparent alt. of ⊙ 47° 31′, of ☾ 36° 52′, app. dist. 48° 20′ 29″. Sun's correction 47″, that of ☾ 45′ 35″.

First calculate the angle Z—in this step it is best to use logarithms to five figures—and whilst taking out the logarithms necessary for this step, take out also—to four places—those of the sin and cos of the side s diminished by half the parallax in altitude, and of m increased by $\frac{1}{2}$ 47″.

m' 42° 29′ 0″	9·82954	Also 9·8296 and 9·8677 log cos m
s' 53 8 0	9·90311	,, 9·9009 ,, 9·7819 ,, s
z' 48 20 29	9·73265	
2)143 57 29		
71 58 44	9·97815	
−48 20 29		
23 38 15	9·60309	
	9·58124	Z = 65° 42′ 45″. Its log cos 9·6142
	−9·73265	
	9·84859	

* Cos z = cos m . cos s + sin m . sin s . cos Z.

In this inquiry Z is always constant, and whilst considering the effects upon s and m separately, the opposed side m or s will be constant.

$$\therefore -\sin z \frac{dz}{ds} = -\cos m \,.\, \sin s + \sin m \,.\, \cos s \,.\, \cos Z,$$

$$\text{and } \therefore dz = ds \left(\frac{\cos m \,.\, \sin s - \sin m \,.\, \cos s \,.\, \cos Z}{\sin z} \right).$$

Then using the formula above given

L cos m 9·8677	L sin m 9·8296		
L sin s 9·9009	L cos s 9·7819		
+9·7686	9·6115		
	L cos Z 9·6142		
No. ·5869 +	9·2257	No. ·1682 negative	

Then

·5869		
−·1682		
·4187	Its log 9·6219	
	−L sin z 9·8734	
	9·7485	
	+ log sin δs 8·1225	
	7·8710	Log sin 25′ 32″·6. First approx. of δz.

For $dz_{//}$ use the same elements, but transposed :

Log cos s . sin m 9·6115	Log sin s . cos m 9·7686		
	L cos Z 9·6142		
No. ·4088		9·3828	No. ·2414 negative
−·2414			
·1674	Its log 9·2238		
	−L sin z 9·8734		
	9·3504		
	+ Log sin 47″ 6·3577		
	5·7081	Log sin 0′ 10″·5 = $\delta z''$	

Hence the first correction of the distance is

$$25' 32''{\cdot}6 - 10''{\cdot}5 = 25' 22''{\cdot}1,$$

and the distance becomes 47° 55′ 7″ as a first approximation. Now reduce the original distance by half the calculated correction, and use the sin of this value in the previous computation of δz ; or, what amounts to the same thing, apply to the final term the difference due to this reduced value of log sin z, which in this case (9·8719 instead of 9·8734) amounts to +·0015, and the final term to 7·8725, making $dz_{,} = 25' 38''$.

The value of $\delta z_{//}$ will not be altered appreciably, so the final correction is 25′ 27″·5, and the distance 47° 55′ 1″·5.

A complete solution of this example, using logarithms to seven places, gives the distance 47° 55′ 0″·88.

It may be seen by the formula that when the angle Z is less than 90° if the second and negative term is greater than the first, the distance will be increased by the Moon's parallax in altitude, but in extreme cases the solar (or stellar) refraction may modify the general rule.

Notes on Meteors observed at Penarth, Glamorgan, on 1896, *Nov.* 14. By George Carslake Thompson, LL.M., and H. W. Lloyd Tanner, M.A., F.R.A.S.

Our attention was mainly directed to the region of *Leo Major*. A building behind us cut off the western sky, some trees cut off the south, and we faced east or north-east. We both watched for about four hours after midnight with an interval specified in the following table. After 4 A.M. the observations were continued till 5.20 A.M. by Mr. Carslake Thompson alone. Each observation was recorded and rough notes were written at the time by G. C. T.

The entries in column A1 refer to meteors from the Sickle in *Leo*; A2, from the region above the Sickle; A3 from the region of *β Leonis* or the region between *β* and the Sickle. The entries in column B are of meteors from other directions. The directions of the meteors noted in column C were not determined.

	A			B	C	
Time.	1	2	3			Notes.
Soon after midnight	...	...	...	1	...	
12 35	1	...	...	...	...	
12 45	...	...	1	...	...	
12 52	1	...	...	...	...	
12 57	1	...	...	...	...	Short course with fine train; appeared 3 or 4 degrees eastward of Sickle; direction of course, perpendicular to and bisecting the line joining *γ* and *ζ* Leonis.
1 11	...	1	...	...	...	
1 30	1	...	...	...	...	Very faint and very short course; appeared very near *ζ* Leonis; course inclined upwards at perhaps 30° to line joining *γ* and *ζ*.
1 34	1	...	...	...	...	
1 37	...	...	...	...	1	
1 47	...	...	1	...	...	
1 54	1	...	...	...	...	Fine train from direction *ζ* Leonis Maj. towards *η* or *ζ* Ursæ Maj.
1 54½	1	...	...	1	...	In same line; might have been same one coming into the air again.
1 58	...	...	...	...	...	
2 1	1	...	...	...	...	A very fine one; passed very close to *ψ* and *γ* Ursæ Maj. (perhaps half a degree above them) in a line parallel to the line joining these stars. Train persisted 2 or 3 seconds.

Time.	A 1	A 2	A 3	B	C	Notes.
2 6–7	...	1	...	...	...	
2 6–7	...	...	...	...	1	
2 6–7	...	...	...	...	1	
2 14	1	...	...	...	...	
2 20	...	1	...	...	...	A rather faint one; downwards, past, and to ζ and γ Leonis Maj. (counted as from general direction of Leo, but query; compare two at 4·25 not so counted).
2 26	...	...	...	1	...	
2 27	1	...	...	...	...	
2 29	1	...	...	...	...	
2 30	1	...	...	...	...	
2 30½	1	...	...	...	...	
2 36	1	...	...	...	...	Persistent train.
2 36–7	...	...	...	...	1	
2 36–7	...	...	...	...	1	
2 41	...	...	...	1	...	
2 45	...	1	...	...	...	
2 53	1	...	...	...	...	
2 58	...	1	...	...	...	
3 0	1	...	...	...	...	
3 1	...	...	1	...	...	
3 4	...	1	...	...	...	
3 5	1	...	...	...	...	
3 5½	1	...	...	...	...	
3 6	...	...	...	1	...	
3 6	1	...	...	...	...	
3 7	...	...	...	1	...	
3 7	...	...	...	...	...	
3 9	...	...	...	1	...	
3 14	...	...	...	1	...	
3 15	...	...	...	1	...	
3 20	...	...	...	1	...	
3 20	...	...	...	1	...	
Interval 3 20–3 42						
3 43	1	...	...	...	...	
3 45	1	...	...	...	...	
3 47	...	...	...	...	1	
3 50	...	...	...	1	...	

Time.	A 1	A 2	A 3	B	C	Notes.
3 50	...	1	...	...	...	
3 51	...	...	...	1	...	
3 55	1	...	...	...	...	
3 55½	1	...	...	...	...	
3 56	...	...	...	1	...	
3 58	1	...	...	...	...	
4 0	...	...	1	...	...	
4 0½	...	...	...	1	...	
4 2	1	...	...	...	...	
4 6	1	...	...	...	...	
4 10	...	...	...	1	...	
4 15	...	...	...	...	1	
4 15	...	...	...	1	...	Long course from west to east, nearly parallel to horizon, across Hydra. (?) Sluggish motion and faint train; manifestly not a Leonid.
4 22	1	...	...	...	...	
4 23	1	...	...	...	...	
4 25	...	...	...	2	...	Two faint meteors simultaneously giving downward near δ Leonis Maj.
4 30	...	...	1	...	...	
4 36	1	...	...	...	...	
4 48	1	...	...	...	...	
4 52	...	...	...	1	...	
4 59	...	...	1	...	...	
5 1	1	...	...	...	...	
5 4	...	1	...	...	...	
5 9	1	...	...	...	...	

Ceased observations at 5 20.

A large proportion of the meteors, including most of those that did not come from *Leo*, were faint. About ten seem to have been noted as having brilliant trains; all of these were from the direction of the Sickle. The flight of the meteors in all these cases was very swift. The trains appeared to G. C. T. generally to have a slight greenish tinge, and to give the impression of being broadest in the middle of the course, tapering towards each end.

Up to about 2 A.M. there was a strong moonlight with some amount of light cloud (not persistent), and perhaps some auroral light. After about 2 A.M. the sky was beautifully clear, without moonlight.

Real Paths of 107 *Meteors observed during the Ten Years ending* 1896 *November.* By W. F. Denning.

The following are the heights, radiants, &c. of such fireballs and shooting stars as have been observed at two or more stations in England during recent years, and submitted to comparison and calculation by the writer. Some of the results have been published before in a detached form in the Journals of the Liverpool Astronomical Society and British Astronomical Association, and in *The Observatory* or *Nature*. They are now brought together in a complete form, and arranged according to the day of the year. It is thought this plan will facilitate reference and prevent troublesome searches amongst various publications on the part of those making inquiries into the subject. Many of the observations were made in connection with the meteoric sections of the two societies above named. The principal observers were Mr. H. Corder, Bridgwater; Mr. D. Booth, Leeds; Professor A. S. Herschel, Slough; and the writer, Bristol. Several other observers contributed useful observations, and the abbreviations are :—

T. W. B. .	T. W. Backhouse, Sunderland.
E. R. B. .	E. R. Blakeley, Dewsbury.
D. B. .	D. Booth, Leeds.
H. C. .	H. Corder, Bridgwater.
G. T. D. .	G. T. Davis, Reading.
W. F. D. .	W. F. Denning, Bristol.
J. E. .	J. Evershed, Kenley, Surrey.
A. S. H. .	A. S. Herschel, Slough.
S. A. S. .	S. A. Saunder, Wokingham, Berks.

In the column headed "Velocity" "v." means very, "sw." swift, "m." moderate or medium speed.

The greatest height of any well-observed meteor in the list was that of a small Perseid (No. 65) seen before sunrise on 1893 August 15, which at its first appearance was 126 miles above the Earth's surface.

The height of ordinary meteors is seldom above 100 miles. There are, however, some notable exceptions. A meteor of the first magnitude was seen at the same time on 1890 December 9 by Mr. Booth at Leeds and by myself at Bristol, and the observations, which appear quite consistent, indicate a height of 208 miles at first appearance and 165 at disappearance, but the figures are so exceptional when compared with others that I have, in order to be on the safe side, rejected the observation.

The average values derived from all the results summarised in the table are :—

Height at first appearance	73·6 miles	(106 meteors)	
„ disappearance	45·3 „	(107 „	)
Length of Path	62·1 „	(105 „	)
Velocity	26·9 „	(58 „	)

It must be remembered that these values are from a promiscuous collection of fireballs and shooting stars. Fireballs usually penetrate much lower into the atmosphere than small meteors, and they exhibit a longer flight and slower motion.

Catalogues of the real paths of meteors are not without their uses, as they supply data for after comparison. When one of these objects is seen, and its course determined from several independent observations, it is interesting to see if it accords with any meteor or meteor-shower noticed in preceding years. Thus on 1896 September 10, $9^h\ 3^m$, a brilliant meteor was recorded by many persons in England, and a comparison of the paths showed that it was directed from a radiant at 72°+42° in *Auriga* (No. 72). Now referring to Professor G. von Niessl's Catalogue we find two fireballs as follow :—

No. 78, 1866 Sept. 6	=☽.	Radiant $79^\circ+44^\circ$.
No. 79, 1869 Sept. 8	4 × ☿.	Radiant 70+45.

The inference is therefore that the three objects belonged to one and the same stream. Extending the comparison to meteor showers we shall find the following radiants exhibit a good accordance in date and position :—

Tupman, No. 66, 1870, Aug. 29 . . .	$75^\circ + 45^\circ$
Denning, No. 520, 1885, Sept. 12–15 .	73 + 43
„ No. 549, 1879, Sept. 15–16 .	72 + 41

The mean positions of the radiants of the three fireballs and of the three meteor showers are as follow :—

Fireballs, Sept. 6–10	$73^\circ7 + 43^\circ7$
Meteor showers, Aug. 29–Sept. 16.	73·3 + 43·0

The agreement could scarcely be more satisfactory.

Such materials are also valuable for the purpose of investigating long-continued radiants, or radiants which, like that of the *Perseids*, shift their position amongst the stars. Thus Nos. 8 and 13 showed radiants nearly identical in *Cepheus*, while Nos.

17, 27, 35, &c., are near together in *Libra*. Among such resemblances some may be purely accidental, but the agreements in certain cases are so striking, and particularly those found in the radiants of meteor showers, that they deserve careful attention.

The apparent radiants of fireballs are often not so accurate as could be wished, owing to the nature of the observations which are more or less imperfect and incorrect. Happily, a decided improvement has been shown in recent years both in the number and quality of such records. Though a vast number of brilliant fireballs have been allowed to escape suitable investigation in the past, it is hoped the time will soon arrive when most of these bodies, which appear over Europe and America, will be sufficiently well observed to enable their real paths to be calculated with precision.

Bristol: 1896 *December* 6.

107 *Real paths of Fireballs and Shooting Stars observed in England from* 1886 *to* 1896. By W. F. Denning.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point.	Observers.	Notes.
			h m		miles	miles	miles		α δ ° °		
1	1894	Jan. 1	10 9	2–1	50	34	20	v. sw.	107+25	H. C. and W. F. D.	Left a streak.
2		1	10 44	2	80	77	52	52	185+15	A. S. H. and W. F. D.	Radiant just risen.
3	1895	1	6 43	3–2½	58	47	30	13	233+56	H. C. and W. F. D.	Quadrantid.
4		1	7 23½	1½–1	65	50	41	10	62–12	,, ,,	Left a train of yellow sparks.
5	1894	2	9 40	3–2	65	56	53	21	240+48	A. S. H. and H. C.	Nucleus orange yellow.
6	1888	2	10 58	♃	98	60	109	44	250+57	D. B. and W. F. D.	Radiant $\eta-\theta$ Draconis.
7	1887	19	11 19	2–1	56	28	33	22	174+70	T. W. B. and W. H. S. Monck	Radiant at λ Draconis.
8	1894	25	10 1	☽	89	16	160	18	331+55	W. F. D. and others	Detonated, 45 observations.
9		Feb. 8	0 28	☽	80	20	...	sw.	Hercules	A. A. Rambaut and others.	In bright sunshine.
10		21	7 18	♃	...	30	...	sw.	141+52	W. F. D. and others	Not well observed.
11	1887	26	11 24	4	56	50	21	21	302+53	J. E. and W. F. D.	Radiant near ψ Cygni.
12	1896	Mar. 1	8 32	3–1½	55	55	405	20	18+5	T. W. B. and J. E. Clark	A very long flight. Radiant near horizon.
13	1895	10	14 27	♃–♀	50	23	58	19	330+59	H. C., A. Mee, and others	Seen during a total eclipse of the Moon, 6 obs. of No. 13.
14		10	15 24	♃	80	40	41	sw.	240+63	G. T. D. and others	
15	1896	16	10 13	♀	33	29	63	m.	205–18	R. B. Saul and others	Compare No. 17.
16	1887	27	8 49	1	59	55	23	10	11+35	T. W. B. and W. F. D.	Left a bright train.

No.	Year.	Month and Day.	G M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point.	Observers.	Notes.
			h m		miles	miles	m l s		α δ ° °		
17	1896	Apr. 8	8 20	1 – ♀	65	38	161	20	204 – 9	H. C., J. E., S. A. S., and others	Compare No. 15.
18		12	8 6	☽	118	34	177	19	50 + 42	F. W. Dyson and others	Radiant perhaps at 50 + 31.
19	1895	14	11 44	1	87	71	107	49	316 + 31	A. S. H. and W. F. D.	Compare No. 24.
20	1893	15	9 52	☽	99	40	158	32	15 + 59	Many Observers	Inexact.
21	1895	19	10 59	1 – ♀	91	43	97	33	269 + 30	H. C., E. R. B., W. F. D., and others	A fine Lyrid.
22		19	11 46	1	77	70	40	50	300 + 20	H. C. and W. F. D.	Left an orange streak.
23	1893	20	11 56	3 – 1½	67	48	28	24	198 + 5	A. S. H. and W. F. D.	Compare No. 33.
24		20	12 39½	2 – 1	75	68	35	49	314 + 27	,, ,,	Compare No. 19.
25		20	12 44	4 – 3	77	68	23	sw.	292 + 17	H. C. and W. F. D.	Left a streak.
26	1889	20	10 16	2 – 1	51	46	22	29	301 + 36	A. S. H. and T. W. B.	Radiant γ Cygni.
27		21	10 16	2 – 1	72	54	42	28	218 – 5	A. S. H. and W. F. D.	Radiant μ Libræ.
28	1893	21	13 38	5 – 3	62	45	37	slow	226 + 11	H. C. and W. F. D.	Radiant near β Libræ.
29		21	15 15½	3 – 2	80	65	33	v. sw.	299 ± 0	,, ,,	Left a streak.
30	1894	22	7 36	☽	80	17	120	30	α – β Persei	J. E. and others	Inexact. In twilight, 20 obs.
31	1887	May 8	8 22	☽	70	14	110	18	191 – 5	Many observers	Left a bright train.
32		9	10 27	3	73	50	37	slow	234 + 9	D. B. and W. F. D.	Radiant close to α Serpentis.
33	1893	9	11 21	2	76	40	54	13	202 + 6	S. A. S. and W. F. D.	Compare No. 23.
34	1889	22	10 8	1 – 2	50	58	293	14	63 + 35	G. T. D. and W. F. D.	Radiant on horizon.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point.	Observers.	Notes.
									α δ		
			h m		miles	miles	miles		° °		
35	1889	May 29	10 44	D	59	22	75	8	215−7	D. B. and I. W. Ward	Compare Nos. 27 and 37.
36	1895	June 10	9 59	D	58	44	89	18	259−23	D. B. and others	Broke into three fragments.
37		July 7	10 49	D	53	30	79	9	217−6	F. W. Dyson and others	Compare Nos. 27 and 35.
38	1891	13	12 54	>1	82	50	154	...	58+33	D. B. and J. Sherwen	Left a bright streak.
39	1887	19	10 48	3−2	59	55	18	slow	104+52	J. E. and W. F. D.	Left a streak.
40		21	11 24½	4	65	51	18	sw.	291+47	„ „	Radiant near δ Cygni.
41		22	13 12½	1−4	80	40	41	27	307+44	D. B. and W. F. D.	Radiant near α Cygni.
42	1886	Aug. 4	10 40	D	90	11	168	21	161+59	W. F. D. and others	A brilliant Ursid fireball.
43	1888	5	10 18½	3−1	69	50	41	slow	50+55	G. T. D. and W. F. D.	Perseid. Left a streak.
44		5	10 29½	4−3	69	48	38	sw.	39+57	„ „	„ „
45		5	10 41½	4−3	68	48	41	sw.	43+51	„ „	„ „
46	1896	6	10 6	1	75	49	47	32	42+61	H. C. and W. F. D.	Perseid.
47	1895	7	10 12	3−2	43	28	42	sw.	45+47	„ „	Radiant near α Persei.
48		7	11 4	1−4	74	45	33	m.	333+36	A. S. H., H. C., and W. F. D.	A bright Lacertid.
49		7	11 28	2	105	63	64	sw.	38+57	H. C. and W. F. D.	Perseid. Left a streak.
50	1888	7	10 6	5−3	70	59	28	sw.	66+56	G. T. D. and W. F. D.	Camelid. ? Perseid.
51		8	10 10	4−3	65	52	38	v. sw.	318−13	„ „	A small Aquarid.
52		8	10 21	3	43	28	26	v. sw.	40+60	„ „	Perseid. Left a streak.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point.	Observers.	Notes.
									α δ		
			h m		miles	miles	miles		° °		
53	1888	Aug. 8	10 27½	4	68	48	36	sw.	42+57	G. T. D. and W. F. D.	Perseid. Left a streak.
54		8	11 16½	1	71	61	22	sw.	60+48	T. W. B. and D. B.	Radiant near μ Persei.
55	1887	10	10 47	2	111	43	120	sw.	44+54	T. W. B. and W. F. D.	Perseid. Left a streak.
56	1893	10	11 0	1	38	23	35	7	304−13	H. C. and W. F. D.	Motion very slow.
57		10	11 55½	1−♃	107	60	69	sw.	43+59	,, ,,	Perseid. Left a streak.
58	1894	10	11 35	1−♃	52	16	54	sw.	43+58	T. W. B. and E. R. B.	,, ,,
59	1896	10	10 6½	2	64	46	35	sw.	44+58	S. J. Johnson and W. F. D.	,, ,,
60		10	10 6¾	2	65	52	27	sw.	44+58	,, ,,	,, Inexact.
61	1895	11	10 7	4	78	62	30	43	48+60	A. S. H. and W. F. D.	,,
62		11	10 58½	1	95	61	53	53	36+57	A. S. H. and H. C.	,, Left a streak.
63		11	11 42½	♃	75	52	34	22	32+52	,, ,,	,, ,,
64	1888	13	11 33½	☽	79	47	48	sw.	43+56	D. B. and W. F. D.	A brilliant Perseid.
65	1887	14	13 46½	4−3	126	87	78	v. sw.	53+57	,, ,,	A Perseid at unusual height.
66	1893	14	11 0	1	60	43	15	slow	294+51	H. C. and W. F. D.	Cygnid. Very short path.
67		15	11 57½	♃	58	21	61	20	186+74	,, ,,	Radiant near χ Draconis.
68	1887	21	11 2	♀	80	45	40	13	264+61	D. B. and W. F. D.	,, ,, ξ ,,
69		21	11 25	4	71	51	26	34	35+63	,, ,,	,, ,, ϵ Cassiopeiæ.
70	1894	26	10 20	☽	90	30	66	sw.	305+79	H. C. and others	Streak lasted 30m.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point.	Observers.	Notes.
									α δ		
			h m		miles	miles	miles		° °		
71	1888	Aug. 26	8 18	☽	66	41	25	sw.	278+52	D. B. and W. F. D.	Left a train.
72	1896	Sept. 10	9 3	< ☽	82	65	78	31	72+42	T. E. R. Phillips and many others	Streak lasted $\frac{1}{2}^m$, 7 obs.
73		10	10 26	☽	71	30	44	15	330+71	H. C., W. F. D., and others	Radiant near β Cephei, 15 obs.
74	1888	12	10 $2\frac{1}{2}$	1	61	38	24	v. sw.	301+46	G. T. D. and J. E.	,, ,, δ Cygni.
75	1889	25	8 5	1	46	46	100	$8\frac{1}{2}$	244−22	W. H. Robinson and W. F. D.	,, on WSW. horizon.
76	1891	30	10 $2\frac{1}{2}$	♃ − ♀	54	24	56	13	14+7	D. B. and W. F. D.	,, at ε Piscium.
77	1893	Oct. 1	9 40	☽	105	28	93	v. slow	265+65	H. C. and others	Inexact.
78	1887	13	10 25	2−1	69	50	26	sw.	73+61	D. B. and W. F. D.	Radiant in Camelopardus.
79		13	11 25	4−2	70	42	37	sw.	127+83	,, ,,	,, ,,
80		14	12 $5\frac{1}{2}$	5−4	64	40	26	m.	355+36	,, ,,	,, Andromeda.
81		15	14 $48\frac{1}{2}$	3−$1\frac{1}{2}$	89	61	39	m.	87+15	,, ,,	Orionid. Left a streak.
82		20	11 45	4	106	90	34	sw.	87+15	,, ,,	,, at unusual height.
83		20	12 55	$1\frac{1}{2}$−1	92	53	70	sw.	87+$13\frac{1}{2}$	,, ,,	,, Left a streak.
84		20	14 15	2−1	74	41	43	slow	20+22	,, ,,	Radiant near φ Piscium.
85	1893	Nov. 12	6 53	1−♃	66	36	91	18	40+6	H. J. Townshend and W. F. D.	,, ,, α Ceti.
86	1896	12	11 8	< ♀	52	29	35	...	45+4	G. T. D. and others	Not very certain.
87		12	15 4	> 1	84	54	41	41	66+18	A. S. H. and H. C.	A bright Taurid.
88		12	15 44	1−♀	100	71	33	v.sw.	138+34	A. S. H. and H. C.	Same radiant as No. 97.
89	1888	13	17 19	> ♃	65	37	34	sw.	149+25	T. W. B. and W. F. D.	A fine Leonid. Streak for 9m
90	1895	14	6 20	2	49	29	40	slow	319−9	H. C., G. T. D., and S. A. S.	A very late Aquarid.

No.	Year.	Month and Day.	G.M.T.	Mag.	Height at Appearance.	Height at Disappearance.	Length of Obs. Path.	Velocity.	Radiant Point. α δ	Observers.	Notes.
			h m		miles	miles	miles		° °		
91	1896	Nov. 14	13 54	>1	95	61	85	63	150+22	A. S. H. and G. C. Thompson	A bright Leonid.
92		14	14 1½	♃	85	49	70	46	148+20	A. S. H. and G. C. Thompson	A bright Leonid.
93		14	14 29	1−♂	92	55	60	v.sw.	150+23	A. S. H. and H. C.	A bright Leonid.
94		14	17 27	1−♃	100	71	33	33	149+24	H. C. and W. F. D.	Leonid.
95*		14	17 45	3	75	50	29	58	150+24	A. S. H., H. C., and W. F. D.	Leonid.
96		14	17 45	3−2	127	89	45	45	150+22	,, ,,	,, Doubtful.
97		14	18 5	3−2	70	55	16	32	133+32	,, ,,	Very short path.
98	1836	17	7 18	♀	96	21	123	17½	34+19	W. F. D. and others.	A bright Arietid.
99	1891	22	6 55	>1	60	42	47	9½	57+15	D. B. and H. C.	Taurid. Compare next.
100	1895	22	6 50	☽	34	17	45	22	58+22	A. S. Williams and others	A Taurid fireball.
101	1886	Dec. 4	9 7	♀	65	28	48	v. sw.	162+58	W. F. D. and others	Left a streak 1½m. See No. 42.
102	1888	8	13 24	1	91	76	72	34	179+10	T. W. B. and D. B.	Left a bright streak.
103	1892	9	7 39	1	91	57	75	30	103+38	H. C. and W. F. D.	Geminid. Left a bright streak.
104	1895	11	14 59	1−♃	53	18	63	v. slow	50+30	H. C. and T. H. Foulkes	Radiant W of ξ Persei.
105	1892	12	10 52	>1	60	36	31	20	110+35	A. S. H., H. C., and W. F. D.	Geminid. Left a bright streak.
106		12	11 20	2	85	44	50	38	111+34	H. C. and W. F. D.	Geminid.
107	1886	28	10 28	1	97	39	62	20	77+30	W. F. D. and another	Left a bright train.

* There appear to have been several small Leonids at about $17^h\ 45^m$. No. 95 is, however, an excellent accordance depending upon three good observations. No. 96 is doubtful, and ought perhaps to be rejected.

Catalogue of Real Paths of Large Meteors.

By Professor Gustav von Niessl.

(*Communicated by W. F. Denning.*)

The following real paths of large meteors have been computed by me in recent years.

The descriptions of the objects were partly collected by myself, partly taken from various scientific papers and journals, viz. from Heis's *Wochenschrift für Astronomie*, *Reports of Vienna Academy*, the *Comptes Rendus* of the French Academy, the *American Journal of Science*, and others.

The succession of the several phenomena contained in this list is arranged according to the month and day (beginning with the commencement of the year), without regard to the particular years in which they were observed, as in my opinion this method of tabulation will allow a ready and convenient means of reference.

I have not availed myself of the very numerous and valuable notices and researches in the reports of the Luminous Meteor Committee of the British Association for the Advancement of Science (1848 to 1880), as one may hope that a summary of them will be prepared by Professor Herschel.

It is also to be hoped that a general catalogue of the real paths of fireballs will soon be compiled, and that this will include the results of other workers in this field; for example, Galle, Weiss, Newton, Koerber, &c.

Brünn, Austria:
1896 *November* 12.

List of Paths of Large Meteors &c., Computed by Professor G. von Niessl.

(*Communicated by W. F. Denning.*)

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. English Miles.	Velocity to the Earth (Geocentric).	Radiant Point. α	Radiant Point. δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
1	Jan. 12 (1879)	6 26 (7 23)	Austria	= ☾ *	41	10	124	17	133	+19	6	*Thus: like Moon. Detonating.
2	12 (1879)	6 33 (7 30)	Austria	Large fireball	87	18	124	13	52	−10	6	Detonating.
3	16 (1895)	10 49 (11 49)	Austria	½ ☾	118	31	124	49	196	+56	5	Velocity not accurate.
4	16 (1895)	10 50 (11 50)	Austria	☾	35	31	166	47	172·5	−23·0	24	Detonating.
5	16 (1895)	10 52 (11 54)	Austria, Germany	☾	96	21	177	19	341·1	+56·4	26	Detonating.
6	17 (1890)	3 42 (4 40)	Austria	Brilliant	88	51	265	...	109	+23·5	2	
7	17 (1890)	4 6 (5 9)	Austria-Hungary	½ ☾ − ☾	97	25	353	34	113·6	+21·7	24	Detonating.
8	23 (1876)	4 44 (5 49)	Austria-Hungary	⅓ ☾	64	16	128	16	17	−20	5	
9	25 (1895)	6 51 (7 53)	Austria	About = ☾	97	31	83	23	104	+30	27	Detonating.

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time). h m	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. Engl'sh Miles.	Velocity to the Earth (Geocentric).	Radiant Point. α °	Radiant Point. δ °	Number of Observations Used.	Remarks, References, &c.
10	28 (1870)	5 31 (5 58)	Germany	3 × ♀	51	31	64	...	19·5	−20	2	See accounts in Heis's *Wochenschrift für Astronomie*, 1870.
11	Feb. 3 (1836)	7 55 (8 20)	Switzerland, France	Very large	138	48	248	62	120	− 7	3	See Heis's investigations in *Jahn, Unterhaltungen*, T. x.
12	3 (1882)	2 7 (3 45)	Hungary	Very large	115	5	297	...	264	+40	4	The Mocs Meteorites. Detonating.
13	10 (1875)	5 51 (6 0)	France	Of a singular magnitude	119	...	...	...	53	+50	4	Only radiant well determinable. *Comptes Rendus*, T. lxxx.
14	12 (1875)	15 45 (10 30)	United States	More than ☾	37	2·5	115	11	104	−30	9	The Marengo (Amana) Meteorites. See Leonard's account in *Americ. Journ. of Science and Arts*, Ser. 3, Vol. x. Detonating.
15	15 (1865)	5 29 (6 0)	Germany	☾	115	28	193	24	279	+60	4	See accounts in Heis's *Wochenschrift*, 1865.
16	20 (1870)	9 33 (10 5)	Italy	Bright meteor	46	23	69	23	273	+62	2	See accounts in Heis's *Wochenschrift*, 1870.
17	24 (1871)	9 9 (10 14)	Austria	♀	90	33	87	44	210	+55	2 (by Meteoroscopes)	
18	Mar. 4 (1872)	9 29 (10 1)	Italy	♃	62	36	37	37	115	+83	3	

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. English Miles.	Velocity to the Earth (Geocentric).	Radiant Point. α	Radiant Point. δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
19	9 (1822)	15 0 (10 0)	United States	⊙	41	29	76	40	257	+40	Many	See Dean's accounts in *Gilbert's Annalen*, T. lxxv., and *Poggendorf*, T. ii. Detonating.
20	13 (1883)	6 22 (7 21)	Austria	Large fireball	102	24	117	39	149	− 9	8	
21	17 (1871)	10 40 (10 49)	France	Large	115	...	more than 550	more than 18	345	+50	8	See accounts in *Comptes Rendus*, T. lxxii.
22	21 (1877)	5 59 (7 4)	Austria, Italy	> ♀	184	18	600	15	55	− 9	4	Scarcely accurate.
23	25 (1873)	7 30 (8 20)	Denmark	½ ☾	80	23	60	24	175	+55	4	See accounts in Heis's *Wochenschrift*, T. 1873.
24	Apr. 2 (1852)	6 25 (6 30)	France	Splendid meteor	10	9	83	12	215	+17	2	See Petit's investigations in *Comptes Rendus*, T. xxxv.
25	2 (1891)	7 50 (8 57)	Austria	½ ☾ − ☾	109	17	180	24	29·0	+55·2	28	Detonating.
26	9 (1876)	7 15 (8 38)	Austria-Hungary	☾	101	20	197	26	17	+57	7	Detonating.
27	10 (1874)	7 4 (8 4)	Austria	2 × ⊙	48	18	56	14	19	+57	6	Detonating.
28	11 (1869)	10 3 (10 35)	Italy	Bright meteor	96	57	40	...	207	+49	2	

Ref. No.	Date or Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen. English	Height. When Last Seen.	Real Length of Observed Path. Miles.	Velocity to the Earth (Geocentric).	Radiant Point. α	Radiant Point. δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
29	11 (1871)	9 14 (9 46)	Italy	Bright meteor	...	25	...	...	216	−10	3	
30	21 (1887)	8 0 (8 58)	Austria	☾	82	23	223	25	214	−13	15	Detonating.
31	22 (1871)	10 5) (10 37)	Italy	Bright meteor	...	43	...	...	231	− 7	2	Radiant, not accurate, but probably not identical with the former of Apr. 21.
32	22 (1888)	6 52) (7 55)	Austria	¾ ☾	116	23	185	20	103·7	+10·1	4½	
33	29 (1877)	8 37 (10 17)	Sweden	☾	42	19	73	21	146·5	± 0	4	See Sundell's account in *Finska Vetenskaps Societ. Förhandl.* T. xxvii.
34	May 5 (1869)	6 2 (6 32)	Germany	Large	30	5	48	24	190	+ 8	3	The meteorite of Krähenberg. See *Neumayer in Vienna Acad.* T. lx. Detonating.
35	14 (1864)	8 0 (8 0)	France	☾	174	14	418	19	86·5	+24·0	11	The meteorites of Orgueil.
36	20 (1869)	16 17 (11 25)	United States	Very large	53	28	46	...	240	−18	3	See Loomis's accounts in *Amer. Jour.* Ser. II. Vol. xlviii. Detonating.
37	26 (1751)	4 56 (6 0)	Austria-Hungary	☾	118	28	280	...	60	+20·5	2	Ironfall at Hradschin. Detonating.
38	28 (1880)	7 26 (8 39)	Austria-Hungary	½ ☾	51	27	74	12	100	+35	2	

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. English Miles.	Velocity to the Earth (Geocentric).	Radiant Point. α	Radiant Point. δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
39	June 2 (1886)	9 59 (11 0)	Austria	> ♃	...	25	...	...	250	−20	4	Not accurate.
40	3 (1842)	8 51 (9 0)	France	⊙	130	11	165	30	272	+46·5	5	See Petit's accounts in *Comptes Rendus*, T. xiv. and xvi. Detonating.
41	3 (1883)	8 44 (9 50)	Austria	Splendid meteor	124	21	332	22	249·9	−20·2	11	
42	3 (1883)	10 39 (10 57)	North Sea	☾	188	23	454	23	248	−20	6	
43	7 (1858)	9 29 (10 0)	Germany	Brilliant meteor	85	18	115	53	256	+ 2	5	See Heis's accounts in *Wochenschrift*, 1858.
44	8 (1888)	17 24 (18 30)	Germany	Large	28	4	86	...	90	+28	3	= June 9, 6ʰ 30ᵐ A.M. in full sunshine. Detonating.
	(1841)	8 13 (8 22)	France	> ♀	115	87	468	43	266	−16	3	See Petit's account in *Comptes Rendus*, T. xiii.
46	9 (1866)	3 32 (4 56)	Austria-Hungary	⊙	36	7	29	...	170	+55	4	The *Knyahinya Meteorite*. Detonating.
47	9 (1869)	8 26 (9 7)	Germany	Large meteor	128	28	119	27	250	+35	7	See Heis's account in *Wochenschrift*, 1869.
48	11 (1867)	8 8 (8 11)	France Germany	Almost ☾	71	41	93	...	86	+44	6	
49	14 (1877)	8 43 (8 52)	France	Splendid	140	27	134	34	215	+14	3	See Grueys' investigations in *Comptes Rendus*, T. lxxxv. Detonating.

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time)	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen	Real Length of Observed Path, English Miles.	Velocity to the Earth (Geocentric).	Radiant Point α	Radiant Point δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
50	17 (1868)	8 18 (9 23)	Austria	½ ☾	...	32	...	...	109	+37	3	A rough determination.
51	17 (1873)	7 38 (8 45)	Austria-Hungary	½ ☉	92	20	281	28	248·6	−20·2	25	Detonating.
52	17 (1885)	8 47 (10 0)	Bosnia	☾	57	30	130	30	112	+42	6	
53	19 (1887)	9 23 (10 25)	Austria	Bright meteor	122	21	360	...	282	−19	4	
54	July 7 (1892)	8 2 (9 0)	South Europe	⅛ ☾	46	98	836	54	349	+ 8	21	True course upwards.
55	8 (1856)	11 38 (6 0)	United States	Large meteor	34	7	37	...	157	+15	4	See Spillman's accounts in *Amer. Journ.* Vol. xxii. and xxiii. Detonating.
56	8 (1876)	14 31 (8 45)	United States	Large	88	34	150	...	305	+ 6	...	See Kirkwood's investigations in *Proceed. of the Amer. Philosph. Soc.* 1877.
57	13 (1879)	7 30 (8 27)	Austria	½ ☾	60	19	119	25	246	−19	10	Detonating.
58	16 (1871)	6 45 (7 34)	Germany	10 × ♀	23	22	48	...	294	−15	2	See Heis's accounts in *Wochenschr*, 1871. Detonating.
59	17 (1876)	7 28 (8 33)	Austria	♀	102	49	55	18	260	+45	3	

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. English Miles.	Velocity to the Earth (Geocentric).	Radiant Point. δ	Radiant Point. α	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
60	20 (1860)	14 43 (9 35)	United States	Large meteor	126	42	1000 at least	12·5	159	+19	6	See Lyman's account in *Americ. Journ.* Vol. xxx.
61	22 (1888)	7 3 (7 55)	Adria	Bright	...	21	...	...	227	+21	4	Observations incomplete, determinations only rough.
62	26 (1873)	9 18 (10 23)	Austria-Hungary	♀	50	46	23	...	250	−29	2 (by Meteoroscopes)	
63	30 (1873)	8 31 (9 12)	Germany	> ♀	82	35	184	41	317	−11	2	See Heis's accounts in *Wochenschr.*, 1873.
64	30 (1879)	9 51 (10 42)	Denmark	♀	107	46	83	...	330	+22·5	2	See Kohl's accounts in Klein's *Wochenschrift*, 1879.
65	Aug. 2 (1860)	15 41 (10 5)	United States	Brilliant meteor	109	28	370	32·5	317	−23	8	See Prof. Newton's accounts in *Amer. Journ.* Ser. II. Vol. xxxiii. Detonating.
66	4 (1858)	9 9 (9 40)	Germany	½ ☾	78	28	70	14	208	+51	4	See accounts in Heis's *Wochenschr.*, 1858 and 1863. Detonating.
67	6 (1864)	10 20 (10 51)	Germany	> ♀	106	36	142	38	305	− 8	5	See Heis's accounts in *Wochenschr.*, 1867.
68	7 (1859)	7 59 (8 30)	Germany	Large meteor	138	27	110	24	264	+53	2	See Heis's accounts in *Wochenschr.*, T. ii. Detonating.
69	10 (1858)	8 32 (9 3)	Germany	⅔ ☾	128	50	92	23	215	+55	3	See Heis's accounts in *Astr. Nachr.* 1186.

Ref. No.	Date of Appearance.	Time, G.M.T. and Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen	Real Length of Observed Path. English Miles.	Velocity to the Earth. (Geocentric).	Radiant Point. α	Radiant Point. δ	Number of Observations Used.	Remarks, References, &c.
		h m							°	°		
70	10 (1863)	8 55 (9 45)	Italy	♀	73	18	...	...	30	+70	2	Not a Perseid.
71	12 (1880)	10 44 (11 34)	Norway and Denmark	♀	79	37	166	17	257·5	− 3	3	See Kohl's investigations in Klein's *Wochenschr.*, 1880.
72	17 (1859)	8 17 (8 53)	Germany	½ ☾	83	21	119	43	335	+17·0	5	See Heis's accounts in *Wochenschr.* T. iii. Detonating.
73	19 (1847)	9 14 (9 23)	France	2 × ♃	108	22	266	23	253	−16·5	2	See Petit's accounts in *Comptes Rendus.* T. xxv. and T. xxix.
74	19 (1867)	8 37 (9 18)	Germany	3 × ♃	158	27	133	30	279	+43	3	See Heis' accounts in *Wochenschr.*, 1867.
75	25 (1884)	8 23 (9 25)	Austria	Very splendid	45	32	69	...	10	+ 5·5	2	
76	26 (1858)	18 45)	Germany	☾	44	41	64	41	11	± 0	2	See Heis's accounts in *Wochenschr.* T. ii. Rad. not accurate.
77	Sept. 5 (1868)	8 0 (8 0)	Servia to France	> ♃	483	115	1770	41	13·9	− 2·0	12	One of the longest paths.
78	6 (1866)	6 50 (7 55)	Austria	☾	37	32	73	...	79	+44	2	
79	8 (1869)	6 17 (7 22)	Austria, Italy	4 × ♃	115	46	734	73	70	+45	Many, but rough	

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent. Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path. Miles.	Velocity to the Earth (Geocentric).	Radiant Point α	Radiant Point δ	Number of Observations Used.	Remarks, References, &c.
		h m			English Miles.				°	°		
80	19 (1873)	10 38 (9 10)	Germany	☾	69	23	106	21	208	+50	2	See accounts in Heis's *Wochenschr.*, 1873.
81	27 (1870)	5 27 (6 8)	Germany, Denmark	Large meteor	184	10	450	44	150	+30	18	See a discussion of Dr. Matthiesen's account in *A.N.*, 1845 and 1846.
82	Oct. 12 (1856)	5 5 (6 0)	Austria	Splendid meteor	73	18	110	...	224	+25	3	
83	13 (1879)	5 0 (5 51)	Italy	2 × ♃	138	20	220	13	304·5	−11	5	
84	23 (1805)	6 22 (6 58)	Germany	2 × ♀	55	37	101	29	52	+16·5	3	See accounts in *Gilbert's Annalen.* T. xxiii.
85	23 (1887)	3 19 (4 20)	Austria	☾	136	20	322	30	224	− 8	10	Detonating.
86	23 (1889)	4 17 (5 29)	Austria-Hungary	¼ ☾	105	23	168	14	311·4	−11·3	9	
87	29 (1857)	5 57 (6 6)	France	Large meteor	83	37	179	23	231	+ 6	2	See Petit's accounts in *Astr. Nach.*, 1180.
88	Nov. 1 (1857)	5 55 (6 26)	Germany	⅕ ☾	157	13	161	...	294	+42	2	
89	11 (1864)	5 35 (6 8)	France, Germany	½ ☾	106	30	446	68	55	+21	6	See accounts in Heis's *Wochenschr.*, 1864.
90	11 (1879)	4 44 (5 34)	Austria	Splendid meteor	50	46	11	...	271	−11	3	

Ref. No.	Date of Appearance.	Time, G.M.T. and (Local Time).	Locality.	Apparent Size or Magnitude.	Height. When First Seen.	Height. When Last Seen.	Real Length of Observed Path.	Velocity to the Earth (Geocentric).	Radiant Point.		Number of Observations Used.	Remarks, References, &c.
					English Miles.				α	δ		
		h m							°	°		
91	13 (1873)	7 48 (8 30)	Germany	⅓ ☾	57	18	64	22	84	+51	2	See Heis's accounts in *Wochenschr.*, 1873.
92	Dec. 4 (1885)	6 32 (7 34)	Austria	Brilliant meteor	48	34	110	18	301·4	−12·8	2	
93	7 (1865)	7 40 (7 30)	France	< ☉	64	45	92	9	296	+11	4	See Gruey's accounts in *Comptes Rendus.* T. lxii. Detonating.
94	7 (1868)	3 30 (4 8)	Germany	☿	56	41	165	14	43	+ 4	3	See Heis's account in *Wochenschr.*, 1868.
95	13 (1888)	5 54 (6 52)	Austria, Germany	♀	85	19	136	27	78	+22	6	
96	17 (1857)	4 18 (4 54)	Germany	Large meteor	48	18	207	34	293	−20	4	See accounts in Heis's *Wochenschr.*, 1858.
97	21 (1887)	3 51 (5 0)	Austro-Hungary	☾	55	29	68	19	273	+19·5	5	
98	24 (1850)	6 18 (6 27)	France	Large meteor	50	24	27	5	0	+50·7	2	See Petit's account in *Comptes Rendus.* T. xlii. Detonating.
99	24 (1873)	12 47 (7 39)	United States	☾	87	9	230	34	109	+26	20	See account by Cleveland Abbe, Washington *Phil. Society's Transact.*, 1874. Detonating.
100	31 (1888)	7 40 (8 8)	France, Germany	♀	74	46	336	...	235	+42	3	See account in Klein's *Wochenschr.*, 1889.

Observations of Comet, 1896, I. (Perrine-Lamp), at the Radcliffe Observatory, Oxford.

(Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.)

The following comet observations (with the exception of March 4) were made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100. The observation on March 4 was made with the Heliometer, using the ring micrometer, with power 100.

Date. 1896.	G.M.T. h m s	Local Sidereal Time. h m s	Observer.	Comet *minus* Star (corrected for Refraction only). R.A. m s	N.P.D. ′ ″	No. of Comps.	Apparent R.A. of Comet. h m s	Parallax in R.A. *v*. s	Log. $(\rho \times \Delta)$.	Apparent N.P.D. of Comet. ° ′ ″	Parallax in N.P.D. *q*. ″	Log. $(q \times \Delta)$.	Ref.
Feb. 23	16 46 12	14 55 28	R.	−1 13·41	−8 33·5	5	21 22 25·31	−1·11	9·6340	57 22 23·3	14·1	0·7377	(*a*)
23	16 49 58	14 59 14	R.	−1 49·20	−8 55·6	3	21 22 29·39	−1·11	9·6348	57 21 39·4	14·2	0·7416	(*b*)
23	17 53 31	16 2 57	R.	−2 18·60	−6 9·0	2	21 23 30·33	−1·11	9·6321	57 9 36·4	13·7	0·7259	(*c*)
Mar. 3	9 19 19	8 2 50	R.	+1 11·40	+1 21·3	8	1 6 0·30	+1·07	9·7572	38 14 58·2	6·0	0·5077	(*d*)
4	8 26 21	7 13 40	R.	+1 23·49	−0 47·2	8	1 24 57 31	+1·05	9·7702	38 14 34·4	7·2	0·6089	(*e*)
14	9 31 33	8 58 29	R.	−1 49·11	+6 8·1	9	3 14 33·50	+0·59	9·7334	42 16 48·2	4·8	0·6396	(*f*)
16	10 4 39	9 39 33	R.	−1 15·09	+2 25·5	8	3 25 42·52	+0·54	9·7270	43 6 39·0	4·6	0·6509	(*g*)
19	8 5 44	7 57 11	W.	+1 25·57	...	10	3 38 49·13	+0·43	9·6756	...	...	...	(*h*)
19	8 5 44	7 57 11	W.	+1 20·70	−5 58·8	10	3 38 48·71	+0·43	9·6756	44 11 9	2·9	0·4942	(*i*)
Apr. 9	9 58 36	11 8 6	R.	−3 34·04	−0 54·1	8	4 29 30·09	+0·26	9·6798	48 48 10·3	2·5	0·6617	(*j*)
10	9 19 31	10 32 51	R.	−0 51·33	−1 26·9	6	4 31 1·07	+0·26	9·6851	48 55 49·8	2·8	0·7140	(*k*)

Observers' Remarks.

(*a*), (*b*), (*c*) Coma is 2′ in diameter. Nucleus diffused, mag. 9 or 10. The comet is visible in the 3-inch finder.

(*c*) Very faint, strong twilight.

(*d*) The comet's coma is, approximately, 3′ in diameter. The nucleus (a large nebulous image, say 15″) is brighter than on February 23.

(*e*) Condensation bright, but more nebulous than with Barclay last night.

(*f*) Coma of comet 2′ diameter; condensation seemed stellar at times, mag. 10. The comparison star is reddish. Sky hazy.

(*g*) Coma 2′ in diameter, with a nebulous condensation. Nucleus visible at times, mag. 11. Sky hazy at intervals.

(*h*), (*i*) The comet is a round diffused mass, with a stellar brightening showing occasionally as a nucleus of about the 13th magnitude. A very small star was close to the comet's nucleus at about $8^h\ 10^m$ G.M.T. Moon near, but sky clear. Observing almost impracticable at times, noises.

(*j*) There is no nucleus, but a slight condensation shows up at times. Diameter of coma 1′. A bright star, *e Persei*, in the field.

(*k*) Observations rather difficult. Coma large, but feeble. A star, magnitude 12 or 13, follows within the condensation, which is only faintly visible. Wind slightly gusty, causing occasional small vibrations of the telescope.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson.

Assumed Places of Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	21 23 39·67	−0·95	57 30 48·0	+ 8·8	Leiden A. G. Zone 90, No. 48, and Zone 100, No. 116.
(*b*)	21 24 19·54	−0·95	57 30 26·2	+ 8·8	Leiden A. G. Zone 90, No. 49, and Zone 100, No. 117.
(*c*)	21 25 49·89	−0·96	57 15 36·8	+ 8·6	Leiden A. G. Zone 90, No. 51, and Zone 100, No. 119.
(*d*)	1 4 50·09	−1·19	38 13 49·3	−12·4	Radcliffe Transit-Circle observations, 1896, September 23, November 18.
	1 23 34·86	−1·04	38 15 35·2	−13·6	Radcliffe Transit-Circle observations, 1896, October 21, November 6.
(*f*)	3 16 22·58	+0·03	42 10 57·4	−17·2	Bonn A. G. 2817.
(*g*)	3 26 57·49	+0·12	43 4 30·7	−17·1	Bonn A. G. 2999.
(*h*)	3 37 23·37	+0·19	...	...	Bonn A. G. 3125.
(*i*)	3 37 27·82	+0·19	44 17 24·6	−16·7	Bonn A. G. 3126. This star has proper motions; not applied.
(*j*)	4 33 3·73	+0·40	48 49 18·6	−14·3	Barclay Equatorial comparisons with Bonn A. G. 3748 and 3776.
(*k*)	4 31 52·02	+0·38	48 57 30·8	−14·1	Bonn A. G. 3748.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, as follows: (*a*), (*b*), (*c*) No. 3335; (*d*), (*e*), (*f*), (*g*), (*h*), (*i*) No. 3338; (*j*), (*k*) No. 3341.

Radcliffe Observatory, Oxford: 1897 *January* 8.

Observations of Occultations of Stars and of Jupiter and his Satellites by the Moon and of Phenomena of Jupiter's Satellites made at the Royal Observatory, Greenwich, in the year 1896.

(*Communicated by the Astronomer Royal.*)

Day	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
I					h m s	
Feb. 25	Disapp. W.B. (2) VII. 1457	Sheepshanks Equat.	100	Dark	7 57 29·69	D.
25	,, ,,	Astrographic Equat.	120	,,	7 57 29·48	R. C.
25	,, ,,	Altazimuth	100	,,	7 57 29·72	S.
Mar. 1	Reapp. Piazzi XII. 196	Sheepshanks Equat.	100	,,	14 44 32·47	H.
19	Disapp. 18 Tauri	Altazimuth	100	,,	7 41 35·19	D.
	,, ,,	Sheepshanks Equat.	120	,,	7 41 33 26	H.
19	,, ,,	Finder of Astrographic Equat.	...	,,	7 41 34·76	J.
27	,, 79 Leonis	28-inch Equat.	670	,,	9 57 47·50	L.
27	,, ,,	Sheepshanks Equat.	100	,,	9 57 47·05	B.
27	,,	Astrographic Equat.	225	,,	9 57 47·45	D. E.
27	,, ,,	Altazimuth	100	,,	9 57 47·55	S.
27 (*a*)	Reapp. ,,	28-inch Equat.	670	Bright	10 55 0·45	L.
27 (*b*)	,, ,,	Transit Circle	195	,,	10 54 59·23	B.
27	,, ,,	Astrographic Equat.	225	,,	10 54 59·72	D. E.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
1896.						
Mar. 27	Reapp. 79 Leonis	Sheepshanks Equat.	100	Bright	10 54 59·49	S.
Apr. 26	Disapp. 83 Virginis	Astrographic Equat.	225	Dark	9 53 48·45	J.
26 (*c*)	Reapp. ,,	,,	225	Bright	11 1 25·34	,,
May 18	Disapp. W.B. (2) VIII. 1240	Sheepshanks Equat.	100	Dark	8 44 39·55	W. S.
21	,, *v* Leonis	,,	100	,,	10 46 9·92	A. C.
21	,, ,,	Altazimuth	100	,,	10 46 10·31	S.
June 14 (*d*)	,, Jupiter's Satellite IV.	28-inch Equat.	670	,,	9 40 47·19	D.
14	,, ,,	Sheepshanks Equat.	100	,,	9 40 46·80	A. C.
14	,, ,,	Detached Tel., No. 2	75	,,	9 40 47·86	B.
14	,, ,,	Altazimuth	60	,,	9 40 (43·15)	C. D.
14	,, ,,	Astrographic Equat.	120	,,	9 40 46·22	H. F.
14	,, Jupiter's 1st Limb	28-inch Equat.	670	,,	9 51 54·85	D.
14	,, ,,	Corbett Tel.	100	,,	9 51 57·35	L.
14	,, ,,	Sheepshanks Equat.	100	,,	9 51 57·26	A. C.
14	,, ,,	Detached Tel., No. 2	75	,,	9 52 (1·05)	B.
14 (*c*)	,, ,,	Altazimuth	100	,,	9 51 59·30	C. D.
14	,, ,,	Astrographic Equat.	225	,,	9 51 57·49	H. F.
14	,, Jupiter's 2nd Limb	28-inch Equat.	670	,,	9 52 47·71	D.
14	,, ,,	Corbett Tel.	100	,,	9 52 44·82	L.

Day.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation.	Observer.
1896.					h m s	
une 14	Disapp. Jupiter's 2nd Limb	Sheepshanks Equat.	100	Dark	9 52 47·12	A. C.
14	,, ,,	Detached Tel., No. 2	75	,,	9 52 47·93	B.
14	,, ,,	Altazimuth	100	,,	9 52 45·96	C. D.
14	,, ,,	Astrographic Equat.	225	,,	9 52 46·45	H. F.
14	,, Jupiter's Satellite I.	28-inch Equat.	670	,,	9 54 57·36	D.
14	,, ,,	Corbett Tel.	100	,,	9 54 56·36	L.
14	,, ,,	Sheepshanks Equat.	100	,,	9 54 57·56	A. C.
14	,, ,,	Detached Tel., No. 2	75	,,	9 55 (0·57)	B.
14	,, ,,	Astrographic Equat.	225	,,	9 54 57·00	H. F.
14	,, Jupiter's Satellite II.	28-inch Equat.	670	,,	9 55 32·96	D.
14	,, ,,	Corbett Tel.	100	,,	9 55 34·26	L.
14	,, ,,	Sheepshanks Equat.	100	,,	9 55 33·57	A. C.
14	,, ,,	Detached Tel., No. 2	75	,,	9 55 34·48	B.
14	,, ,,	Altazimuth	60	,,	9 55 32·71	C. D.
14	,, ,,	Astrographic Equat.	225	,,	9 55 32·30	H. F.
14	,, Jupiter's Satellite III.	28-inch Equat.	670	,,	9 57 56·56	D.
14	,, ,,	Corbett Tel.	100	,,	9 57 57·10	L.
14	,, ,,	Sheepshanks Equat.	100	,,	9 57 57·16	A. C.

Day. 1896.	Phenomenon.	Telescope.	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
June 14	Disapp. Jupiter's Satellite III.	Altazimuth	60	Dark	9 57 56·81	C. D.
14	,, ,,	Astrographic Equat.	225	,,	9 57 55·30	H. F.
22	,, 4 Scorpii	Astrographic Equat.	120	,,	8 57 3·46	C. D.
24	,, Piazzi XVII. 359	,,	120	,,	11 56 8·51	,,
July 20	Reapp. τ Scorpii	Sheepshanks Equat.	55	Bright	8 16 31·17	A. C.
28 (*c*)	Disapp. 21 Piscium	Astrographic Equat.	225	,,	15 9 51·12	C. D.
28	Reapp. ,,	,,	120	Dark	16 8 54·95	,,
Oct. 1 (*c*)	Disapp. ε Cancri	Sheepshanks Equat.	100	Bright	16 40 0·47	W.
1 (*c*)	,, 42 Cancri	,,	100	,,	16 47 7·31	,,
22 (*c*)	,, μ Arietis	Astrographic Equat.	225	,,	7 45 29·15	H.
27	,, 52 Geminorum	,,	225	,,	10 9 58·15	W. B.
Dec. 17	,, η Tauri	Sheepshanks Equat.	100	Dark	4 13 41·59	H.
17 (*c*)	Reapp. 20 Tauri	,,	100	Bright	4 17 54·80	,,
17 (*c*)	,, η Tauri	,,	100	,,	4 38 17·40	,,

Notes.

(*a*) Observer noted that the observed time was probably late.

(*b*) The observed time has been increased by 5 seconds after consultation with the Observer, who was able to verify the alteration by remembering the position of the star at reappearance in the field at the Transit Circle, and to compare with the observed time of transit.

(*c*) Not considered a good observation.

(*d*) The disappearance of the satellite seemed to last about a second.

(*e*) Seemed to be at a slight distance from limb when first seen.

Phenomena of Jupiter's Satellites.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of *N.A.*	Observer.
1896.					h m s	h m s	
Jan. 17	I. (*a*)	Ecl. D. Began to fade	Altaz.	100	6 20 48		H. F.
17	I.	Bisection	,,	,,	6 22 43		,,
17	I.	Last seen	,,	,,	6 24 18	6 22 51	,,
22	I. (*b*)	Ecl. D. Began to fade	Sheepsh. Equat.	120	13 46 0		B.
22	I.	Bisection	,,	,,	13 47 24		,,
22	I.	Last seen	,,	,,	13 48 34	13 48 28	,,
29	III.	Ecl. R. First seen	,,	,,	7 45 36	7 43 25	H.
29	III.	Full brightness	,,	,,	7 48 36		,,
Feb. 6	II.	Ecl. R. First seen	Astrographic Equat.	225	7 47 37	7 48 3	D. E.
11	II. (*c*)	Tr. Ing. First contact	Sheepsh. Equat.	120	11 25 5		B.
11	II.	Bisection	,,	,,	11 29 14	11 28 0	,,
11	II.	Last contact	,,	,,	11 32 24		,,
22	I.	Tr. Ing. First contact	,,	200	12 30 2		H.
22	I.	Bisection	,,	,,	12 31 31	12 32 0	,,
22	I.	Last contact	,,	,,	12 33 56		,,
23	IV. (*d*)	Ecl. R. First seen	,,	120	6 19 52	6 22 27	A. C.
23	IV.	Full brightness	,,	,,	6 23 17		,,
25	I.	Ecl. R. First seen	Altaz.	100	7 9 18	7 8 17	D.

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of *N.A.*	Observer.
1896.					h m s	h m s	
Mar. 1	I.	Ecl. R. First seen	Sheepsh. Equat.	120	14 34 34	14 34 34	H.
1	I.	Full brightness	,,	,,	14 36 30		,,
10	I. (*e*)	Occ. D. First contact	,,	200	7 36 5		,,
10	I.	Bisection	,,	,,	7 39 0	7 41 0	,,
10	I.	Last seen	,,	,,	7 40 54		,,
16	II.	Ecl. R. First seen	,,	120	10 2 47	10 2 46	B.
16	II.	Full brightness	,,	,,	10 4 49		,,
19	III.	Occ. R. First seen	,,	100	7 10 16		H.
19	III.	Bisection	,,	,,	7 11 56	7 15 0	,,
19	III.	Last contact	,,	,,	7 13 16		,,
19	I.	Ecl. R. First seen	,,	,,	7 22 32	7 22 31	,,
19	I.	Full brightness	,,	,,	7 24 14		,,
19	III.	Ecl. D. Last seen	,,	,,	8 10 51	8 9 38	,,
19	III.	Ecl. R. First seen	,,	,,	11 42 3	11 41 42	,,
19	III.	Full brightness	,,	,,	11 45 51		,,
23	II.	Occ. D. First contact	,,	,,	7 25 48		,,
23	II.	Bisection	,,	,,	7 28 3	7 28 0	,,
23	II.	Last seen	,,	,,	7 30 47		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of *N.A.*	Observer.
1896.					h m s	h m s	
Mar. 25	I.	Tr. Ing. First contact	Sheepsh. Equat.	100	8 37 55		B.
25	I.	Bisection	,,	,,	8 41 40	8 40 0	,,
25	I. (*f*)	Last contact	,,	,,	8 45 14		,,
25	I. (*g*)	Tr. Egr. First contact	,,	,,	10 57 17		,,
25	I.	Bisection	,,	,,	11 0 32	11 0 0	,,
25	I.	Last contact	,,	,,	11 3 21		,,
27	IV.	Occ. R. Last contact	28-inch Equat.	670	7 11 48	7 9 0	L.
27	IV. (*h*)	Ecl. D. Last seen	Sheepsh. Equat.	120	13 55 36	13 53 42	B.
30	II. (*i*)	Occ. D. First contact	,,	,,	9 53 50		A. C.
30	II.	Bisection	,,	,,	9 55 31	9 57 0	,,
30	II.	Last seen	,,	,,	9 59 6		,,
Apr. 1	I.	Tr. Ing. First contact	,,	55	10 32 36		H. A.
1	I.	Bisection	,,	,,	10 34 45	10 31 0	,,
1	I.	Last contact	,,	,,	10 37 20		,,
2	I. (*j*)	Occ. D. Last seen	Sheepsh. Equat.	120	7 41 13	7 41 0	W.
2	III.	Occ. D. Bisection	,,	,,	11 7 55	11 6 0	,,
2	III.	Last seen	,,	,,	11 9 9		,,
2	I.	Ecl. R. First seen	,,	,,	11 13 24	11 13 14	,,
2	I.	Full brightness	,,	,,	11 14 39		,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of *N.A.*	Observer.
1896.					h m s	h m s	
Apr. 3	I.	Tr. Egr. Last contact	28-inch Equat.	670	7 21 46	7 19 0	L.
10	I.	Tr. Egr. First contact	Sheepsh. Equat.	55	9 10 10		H. F.
10	I.	Bisection	,,	,,	9 12 19	9 12 0	,,
10	I.	Last contact	,,	,,	9 14 59		,,
13	IV.	Ecl. D. Began to fade	,,	120	7 47 3		H.
13	IV.	Last seen	,,	,,	7 59 56	7 56 58	,,
13	III.	Tr. Egr. First contact	,,	,,	8 34 46		H.
13	III.	Bisection	,,	,,	8 37 40	8 39 0	,,
13	III.	Last contact	,,	,,	8 42 29		,,
15	II.	Tr. Ing. First contact	28-inch Equat.	670	9 18 24		D.
15	II.	Bisection	,,	,,	9 21 4	9 23 0	,,
15	II.	Last contact	,,	,,	9 23 20		,,
15	II.	Tr. Ing. First contact	Corbett Telescope	100	9 15 49		C.
15	II.	Bisection	,,	,,	9 20 50	9 23 0	,,
15	II.	Last contact	,,	,,	9 23 20		,,
17	I. (*k*)	Tr. Ing. First contact	Sheepsh. Equat.	120	8 43 44		H.
17	I.	Bisection	,,	,,	8 46 44	8 46 0	,,
17	I.	Last contact	,,	,,	8 49 28		,,
17	II. (*l*)	Ecl. R. First seen	,,	,,	9 40 52	9 40 31	,,

Day.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation.	Mean Solar Time of *N.A.*	Observer.
1896.					h m s	h m s	
Apr. 17	II.	Full brightness	Sheepsh. Eqat.	120	9 44 49		H.
17	I.	Tr. Egr. First contact	,,	,,	11 5 6		,,
17	I.	Bisection	,,	,,	11 7 35	11 6 0	,,
17	I.	Last contact	,,	,,	11 10 20		,,
May 11	I.	Ecl. R. First seen	,,	,,	9 48 18	9 48 14	B.
19	II. (*m*)	Ecl. R. First seen	,,	55	9 17 1	9 16 55	D. E.
19	II.	Full brightness	,,	,,	9 18 16		,,

Notes.

(*a*) *Jupiter* very ill-defined. (*b*) Definition of limb not very good. (*c*) Rough. (*d*) Twilight. Probably a little late.
(*e*) Clouds passing, but considered a good observation. (*f*) Cloudy. (*g*) Cloudy. (*h*) Sky hazy. *Jupiter* low down.
(*i*) Cloudy. (*j*) Very cloudy. (*k*) Clouds passing.
(*l*) The first time may be late. The planet was occasionally dimmed by clouds, and the reappearance was suspected about a minute before.
(*m*) Cloudy.

The aperture of the 28-inch equatorial is 28 inches; of the Astrographic Guiding Telescope, 10 inches (referred to as Astrographic Equatorial); of the Sheepshanks Equatorial, 6·7 inches; of the Corbett Telescope, 6·5 inches; of the Transit Circle, 8 inches; of the Altazimuth, 4 inches; of Detached Telescope No. 2, 2·7 inches; and of the Finder of the Astrographic Equatorial, 2 inches.

The initials D., C., L., H., A. C., B., H. F., C. D., R. C., D. E., W. B., J., S. W., and W. S. are those of Mr. Dyson, Mr. Cowell, Mr. Lewis, Mr. Hollis, Mr. Crommelin, Mr. Bryant, Mr. Furner, Mr. Davidson, Mr. Cheeseman, Mr. Edney, Mr. Bowyer, Mr. Johns, Mr. Witchell, and Mr. Stevens respectively.

Royal Observatory, Greenwich:
1897 *January* 8.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. FEBRUARY 12, 1897. No. 4

A. A. COMMON, LL.D., F.R.S., President, in the Chair.

George Banks, 4 John Street, Bedford Row, W.C. ;
John Charles Clancey, F.R.G.S., F.S.I., 7 Grafton Square, Clapham Common, S.W. ;
William Fraser Doak, M.A., *Nautical Almanac* Office, 3 Verulam Buildings, Gray's Inn, W.C. ;
Rev. Edward Spry Leverton, M.A., School House, Kirkham, Lancashire ;
Ernest Frederick John Love, M.A., Lecturer in Physics in the University of Melbourne, Australia ;
William Arthur Smith, 78 Hagley Road, Edgbaston, and 94 Charlotte Street, Birmingham ; and
Edward Weldon, 10 Morden Road, Blackheath, S.E.,

were balloted for and duly elected Fellows of the Society.

The following Candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

John Franklin-Adams, Wimbledon (proposed by L. Becker) ;
Rev. Sherrard Beaumont Burnaby, M.A., The Vicarage, Hampstead, N.W. (proposed by B. Woodd Smith) ;
John Sisson Slater, M.A., LL.D., Barrister-at-Law, 1 Garden Court, Temple, E.C., and Seafield House, Lytham (proposed by Sir R. S. Ball) ; and
Rev. John Spence, Minister of Chelsea Chapel, and 27 Walpole Street, Chelsea, S.W. (proposed by W. Willett).

Report of the Council to the Seventy-seventh Annual General Meeting of the Society.

The following table shows the progress and present state of the Society :—

	Compounders	Annual Subscribers	Total Fellows	Associates	Patron	Grand Total
December 31, 1895	245	391	636	46	1	683
Since elected	+6	+27	...	...	...	...
Deceased	...	−12	...	−6	...	...
Resigned	...	−12	...	...	...	...
Removals	+2	− 2	...	...	...	...
Expelled	...	− 1	...	...	...	...
December 31, 1896	253	391	644	40	1	685

Mr. Knobel's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balances, 1896 January 1:—						
At Bankers', as per Pass Book	286	12	10			
Outstanding Cheques	24	6	6			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	8	4			
In hand of Assistant Secretary on Petty Cash Account	3	3	0			
In hand of Assistant Secretary on Account of Sales of Photographs, 1895	20	11	0			
				349	1	8
Dividends on £13,200 Consols, 2¾ per cent. ...	350	18	4			
„ on £900 New 2½-per-cent. Stock ...	21	15	0			
„ on £1,250 Metropolitan 3-per-cent. Stock	36	5	0			
				408	18	4
Received on account of Subscriptions:—						
Arrears	157	10	0			
Annual Contributions for 1896	604	16	0			
„ „ 1897	2	2	0			
Admission Fees	75	12	0			
First Contributions	48	6	0			
				888	6	0
Composition Fees				168	0	0
Sales of Publications:—						
At Williams and Norgate's, 1895	20	13	8			
At Society's Rooms, 1896	37	7	6			
Sale of Photographs, 1896	66	0	6			
				124	1	8
Income Tax refunded by Commissioners of Inland Revenue				14	1	8

Audited and found correct, 1897 January 6.

C. THWAITES,
DAVID SMART,
A. C. D. CROMMELIN.

£1,952 9 4

Astronomical Society, from 1896 *January* 1 *to December* 31.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Assistant Secretary: Salary	250	0	0			
,, ,, for assistance in editing Society's Publications ...	50	0	0			
,, ,, for work in preparation of General Index	60	0	0			
				360	0	0
House Duty	2	12	6			
Fire Insurance	7	16	6			
				10	9	0
Printing, &c., *Monthly Notices*	326	10	9			
,, *General Index*	140	19	0			
,, *Memoirs*, vol. li.	223	8	0			
,, Miscellaneous	42	6	6			
Woodbury type Plates	10	9	0			
Lithography and Engraving	14	15	0			
				758	8	3
Reproduction of Photographs				65	18	11
Turnor and Horrox Fund: Purchases for Library	19	15	3			
Binding Books in Library	37	18	6			
				57	13	9
Coelostat for Eclipse Observation				100	0	0
Clerk's Wages	52	0	0			
Postage and Telegrams	74	7	0			
Carriage of Parcels	2	14	3			
Stationery and Office Expenses	5	17	10			
				134	19	1
Expenses of Meetings	20	0	0			
Lantern Expenses	15	0	3			
				35	0	3
House Expenses	65	3	1			
Coals and Gas	39	0	3			
Electric Light Expenses	13	16	4			
Time Signal	5	0	0			
Sundry Fittings and Repairs	4	16	1			
Sundries	5	12	4			
				133	8	1
Decorating Rooms, balance of Trollope's Account	76	0	0			
Blinds on Staircase	7	1	6			
				83	1	6
Lee and Janson Fund Grants				11	10	0
Deductions on Cheques, &c.				0	3	0
Balances, 1896 December 31:—						
At Bankers', as per Pass Book	186	12	1			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	13	1			
In hand of Assistant Secretary on Petty Cash Account	0	12	4			
				201	17	6
				£1,952	9	4

Report of the Auditors.

We have examined the Treasurer's accounts for the year 1896, and have found and certified the same to be correct. The cash in hand on 1896 December 31, including the balance at the bankers', &c., amounted to £201 17*s.* 6*d.*

The funded property of the Society is the same as at the end of the previous year.

The books, instruments, and other effects in the possession of the Society have been examined, and they appear to be in a satisfactory condition.

We have laid on the table a list of the names of those Fellows who are in arrear for sums due at the last Annual General Meeting of the Society, with the amount due against each Fellow's name.

We consider that the amount for which the Society's property is insured is too small to cover the value of the library, instruments, &c., and suggest that the insurance be increased.

(Signed) DAVID SMART,
ANDREW C. D. CROMMELIN,
C. THWAITES.

1897 *January* 8.

Trust Funds.

The Turnor Fund: A sum of £450 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Horrox Memorial Fund: A sum of £100 2¾-per-cent. Consols, the interest to be used in the purchase of books for the Library.

The Lee and Janson Fund: A sum of £323 16*s.* 6*d.* 2¾-per-cent. Consols, the interest to be given by the Council to the widow or orphan of any deceased Fellow or Associate of the Society who may stand in need of it.

The Hannah Jackson (née Gwilt) Fund: A sum of £300 2¾-per-cent. Consols, the interest to be given in Medals or other awards, in accordance with the terms of the Trust.

Assets and Present Property of the Society, 1897 January 1.

	£	s.	d.	£	s.	d.
Balances, 1896 December 31:—						
At Bankers'	186	12	1			
In hand of Assistant Secretary on account of Turnor and Horrox Fund	14	13	1			
In hand of Assistant Secretary on Petty Cash Account	0	12	4			
				201	17	6
Due on account of Subscriptions:—						
4 Contributions of 4 years' standing	33	12	0			
9 „ 3 „	56	14	0			
35 „ 2 „	147	0	0			
56 „ 1 „	117	12	0			
1 Admission Fee and First Contribution ...	3	3	0			
	358	1	0			
Less 1 Contribution for 1897 paid in advance	2	2	0			
				355	19	0
Due from Messrs. Williams and Norgate for sales of Publications during 1896				34	5	7

£13,200 2¾-per-cent. Consols, including the Lee and Janson Fund, the Turnor and Horrox Fund, and the Jackson-Gwilt Fund.

£900 New 2½-per-cent. Consols.

£1,250 Metropolitan 3-per-cent. Stock.

Astronomical and other Manuscripts, Books, Prints, and Instruments.

Furniture, &c.

Stock of Publications of the Society.

Stock in hand of volumes of the *Memoirs*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I. Part 1	7	...	XXX.	153	...
I. Part 2	42	...	XXXI.	136	...
II. Part 1	51	3	XXXII.	148	...
II. Part 2	17	3	XXXIII.	157	...
III. Part 1	65	1	XXXIV.	159	1
III. Part 2	83	1	XXXV.	105	2
IV. Part 1	78	3	XXXVI.	188	8
IV. Part 2	90	3	XXXVII. Part 1	334	7
V.	101	3	XXXVII. Part 2	279	8
VI.	119	6	XXXVIII.	264	1
VII.	141	3	XXXIX. Part 1	230	3
VIII.	125	3	XXXIX. Part 2	235	3
IX.	132	3	XL.	250	1
X.	144	...	XLI.	398	...
XI.	151	...	XLII.	226	3
XII.	157	...	XLIII.	227	...
XIII.	155	...	XLIV.	207	1
XIV.	363	...	XLV.	240	...
XV.	136	...	XLVI.	220	1
XVI.	161	1	XLVII. Part 1	3	...
XVII.	145	1	XLVII. Part 2	18	...
XVIII.	137	1	XLVII. Part 3	2	...
XIX.	147	...	XLVII. Part 4	10	...
XX.	136	1	XLVII. Part 5	8	...
XXI. Part 1	310	...	XLVII. Part 6	9	...
XXI. Part 2	98	...	XLVII.	194	1
XXI. 1 & 2 (together)	58	...	XLVIII. Pt. 1	243	...
XXII.	160	1	XLVIII. Pt. 2	237	1
XXIII.	144	...	XLIX. Part 1	381	1
XXIV.	151	1	XLIX. Part 2	263	...
XXV.	161	...	L.	258	1
XXVI.	167	1	LI.	325	1
XXVII.	419	1	Index to *Memoirs*	624	3
XXVIII.	378	...			
XXIX.	400	...			

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms	At Williams & Norgate's	Vol.	At Society's Rooms	At Williams & Norgate's
I.	55	...	XXX.	63	2
II.	59	...	XXXI.	91	...
III.	...	...	XXXII.	109	5
IV.	...	...	XXXIII.	91	...
V.	...	...	XXXIV.	68	1
VI.	43	...	XXXV.	52	...
VII.	2	...	XXXVI.	26	1
VIII.	153	2	XXXVII.	33	3
IX.	24	3	XXXVIII.	96	2
X.	172	1	XXXIX.	93	...
XI.	184	...	XL.	105	3
XII.	106	2	XLI.	105	5
XIII.	177	2	XLII.	114	1
XIV.	176	3	XLIII.	111	2
XV.	168	2	XLIV.	114	2
XVI.	154	1	XLV.	115	1
XVII.	167	1	XLVI.	111	...
XVIII.	242	...	XLVII.	128	2
XIX.	52	...	XLVIII.	120	1
XX.	31	...	XLIX.	113	8
XXI.	16	...	L.	115	10
XXII.	30	...	LI.	116	8
XXIII.	17	...	LII.	116	12
XXIV.	22	...	LIII.	117	15
XXV.	13	...	LIV.	117	17
XXVI.	9	1	LV.	131	3
XXVII.	3	...	LVI.	124	7
XXVIII.	70	...	1st Index ...	550	5
XXIX.	51	...	2nd „ ...	850	2
LIBRARY CATALOGUE				549	2

In addition to the above volumes of the *Monthly Notices*, the Society has a considerable stock of separate numbers of nearly all the volumes. With the exception, however, of Vols. XXXVI. to LVI., no complete volumes can be formed from the separate numbers in stock.

Instruments belonging to the Society.

A brief description of the chief instruments and other particulars relating to them will be found in *Monthly Notices*, vol. xxxvi. p. 126.

No. 1. The *Harrison* clock.
„ 2. The *Owen* portable circles, by Jones.
„ 3. The *Beaufoy* circle.
„ 4. The *Beaufoy* transit instrument.
„ 5. The *Herschel* 7-foot telescope.
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Utzschneider and Fraunhofer, of Munich.
„ 7. The *Smeaton* equatorial.
„ 8. The *Cavendish* apparatus.
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's).
„ 10. The variation transit instrument (late Mr. Shearman's).
„ 11. The universal quadrat, by Abraham Sharp.
„ 12. The *Fuller* theodolite.
„ 13. The standard scale, by Troughton and Simms.
„ 14. The *Beaufoy* clock, No. 1.
„ 15. The *Beaufoy* clock, No. 2.
„ 16. The *Wollaston* telescope.
„ 17. The *Lee* circle.
„ 18. The *Sharpe* reflecting circle.
„ 19. The *Brisbane* circle.
„ 20. The *Baker* universal equatorial.
„ 21. The *Reade* transit.
„ 22. The *Matthew* equatorial, by Cooke.
„ 23. The *Matthew* transit instrument.
„ 24. The *South* transit instrument.
„ 25. A sextant, by Bird (formerly belonging to Captain Cook).
„ 26. A globe showing the precession of the equinoxes.
The *Sheepshanks* collection :—
„ 27. (1) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumb-line; portable clamping foot and tripod stand.

No. 29. (3) **Equatorial stand** and clock movement for $4\frac{6}{10}$-**inch** telescope (telescope lost); double-image micrometer; two wire micrometers; object-glass micrometer.

„ 30. (4) $3\frac{1}{4}$-**inch achromatic telescope, with equatorial** stand; double-image micrometer; one terrestrial and three astronomical eyepieces.

„ 31. (5) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

„ 33. (7) 2-foot navy telescope.

„ 34. (8) Transit instrument of 45 inches focal length, with iron stand and also Y's for fixing to stone piers; two axis levels.

„ 35. (9) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, reading to 10″ by two verniers to each circle.

„ 38. (12) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{6}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end, reading to single minutes; horizontal circle 9 inches diameter in brass to single minutes.

„ 40. (14) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; heavy stand for theodolite; Y-piece of level; two large and three small ground-glass bubbles divided; level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires; mercury bottle and trough.

„ 41. (15) Level collimator, with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16) 10-inch reflecting circle by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon, with mercury; two tripod stands.

„ 43. (17) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. Circle divided on silver, reading to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

No. 45. (19) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
„ 46. (20) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
„ 47. (21) Box sextant; reflecting plane and level.
„ 48. (22) Prismatic compass, by Troughton and Simms.
„ 49. (23) Mountain barometer.
„ 50. (24) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25) Ordinary 4½-inch compass with needle.
„ 52. (26) Dipping needle, by Robinson.
„ 53. (27) Compass needle, mounted for variation.
„ 54. (28) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29) Box of magnetic apparatus.
„ 56. (30) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31) Box sextant and glass plane artificial horizon, by Troughton and Simms.
„ 58. (32) Plane 2⅜-inch speculum, artificial horizon and stand.
„ 59. (33) 2½-inch circular level horizon, by Dollond.
„ 60. (34) Artificial horizon, roof, and trough; the trough 8¼ by 4½ inches; tripod stand.
„ 61. (35) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36) A pantograph.
„ 63. (37) A noddy.
„ 64. (38) A small Galilean telescope with object-glass of rock crystal.
„ 65. (39) Five levels.
„ 66. (40) 18-inch celestial globe.
„ 67. (41) Varley stand for telescope.
„ 69. (43) Telescope, with object-glass of rock crystal.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.
„ 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal or star dial.

No. 83. An early non-achromatic telescope, of about 3 feet focal length in oak tube, by Samuel Scatliffe, London.
„ 84. A Hollis observing chair.
„ 85. Double-image micrometer, by Troughton and Simms.
„ 86. 4½-inch Gregorian reflecting telescope, by Short, with altazimuth stand and 6-inch altitude and azimuth circles and two eyepieces.
„ 87. 3¼-inch Gregorian reflecting telescope with wooden tripod stand.
„ 88. Pendulum, with 5-foot brass suspension rod, working on knife-edges, by Thomas Jones.
„ 89. A Rhabdological Abacus. A contrivance invented by Mr. H. Goodwyn, consisting of a box filled with compartments, in which are square rods covered with numbers, which can be arranged so as to facilitate the labour of multiplying high numbers.
„ 90. An Arabic celestial globe of bronze, 5¾ inches in diameter.
„ 91. Astronomical time watch-case, by Professor Chevalier.
„ 92. 2-foot protractor, with two movable arms, and vernier.
„ 93. Beam compass, in box.
„ 94. 2-foot navigation scale.
„ 95. Stand for testing measures of length.
„ 96. Artificial planet and star, for testing the measurement of a fixed distance at different position-angles.
„ 97. 12-cell Leclanché battery.
„ 98. 2-foot 6-inch navy telescope, with object-glass 2½ inches, by Cooke, with portable wooden tripod stand.
„ 99. 12-inch transit instrument, by Fayrer and Son, with level and portable stand.
„ 100. 9-inch transit instrument, with level and iron stand.
„ 101. Small equatorial sight instrument, by G. Adams, London.
„ 102. Sun-dial, by Troughton.
„ 103. Sun-dial, by Casella.
„ 104. Sun-dial.
„ 105. Box sextant, by Troughton and Simms.
„ 106. Prismatic compass, by Schmalcalder, London.
„ 107. Compass, by C. Earle, Melbourne.
„ 108. Prismatic compass, by Negretti and Zambra.
„ 109. Dipleidoscope, by E. Dent.
„ 110. Abney level, by Elliott.
„ 111. Pocket spectroscope, by Browning.
„ 112. Universal sun-dial.
„ 113. Double sextant, by Jones.
„ 114. Two models, illustrating the effects of circular motions.
„ 115. A cometarium.
„ 117. } Two old sun-dials.
„ 118. }
„ 119. Specimens of diffraction gratings, by Prof. W. A. Rogers.

No. 120. A 6-prism spectroscope, by Browning.
„ 121. Spitta's improved maximum and minimum thermometer.
„ 122. A 6-inch speculum, with flat; the speculum said to be by Sir W. Herschel, and re-figured by Sir J. Herschel.
„ 123. A 6-inch refracting telescope, by Grubb, with 3 eyepieces.
„ 124. Position micrometer, by Cooke.
„ 125. A 6-inch refracting telescope, by Simms, with eyepieces and solar diagonal.
„ 126. 3½-inch portable refracting telescope, by Talley, with tripod stand.
„ 127. Globe representing the visible surface of the Moon, by John Russell, R.A. (1797).
„ 128. Bichromate battery and Ruhmkorff coil.
„ 129. Slater's improved armillary sphere.
„ 130. 10-inch brass pillar sextant, by Troughton.
„ 131. Double box sextant, by Cary.

Besides the above, there is the following apparatus available for eclipse work :—

4 Slits for spectroscope.
2 Abney lenses used in photographing the corona.
2 Dallmeyer negative enlarging lenses.
1 Cœlostat with 16-inch plane mirror.

The following instruments are lent, during the pleasure of the Council, to the undermentioned persons :—

No. 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 16. The *Wollaston* telescope, to Mr. R. Inwards.
„ 22. The *Matthew* equatorial, to Mr. J. Brett.
„ 23. The *Matthew* transit, to Captain W. Noble.
„ 27. (1) 30-inch transit and stand, to Mr. B. T. Moore.
„ 28. (2) 6-inch theodolite and stand, to Dr. A. A. Common.
„ 29. (3) Equatorial mounting, clock, &c., to the Rev. C. D. P. Davies.
„ „ Wire micrometer (No. 1), to Mr. C. Thwaites.
„ 30. (4) 3¼-inch equatorial, to Mr. E. B. Powell.
„ 31. (5) 2¾-inch telescope and stand, to Mr. F. J. Wardale.
„ 47. (21) Box sextant and horizon, to Mr. C. H. Johns.
„ 50. (24) Prismatic compass, to Mr. Maxwell Hall.
„ 69. (43) Telescope with rock-crystal object glass, to Dr. W. Huggins.
„ 72. (*a*) Polarimeter, to Dr. A. M. W. Downing.
„ 72. (*c*) Polarimeter, to Professor C. M. Smith.
„ 78. 9⅓-inch reflector and stand, to Mr. Maxwell Hall.
„ 85. Double image micrometer, to Mr. B. T. Moore.

No. 99. 12-inch transit with portable stand, to Mr. H. T. Vivian.
„ 119. Diffraction gratings, to Mr. B. T. Moore.
„ 120. 6-prism spectroscope, to Mr. C. Thwaites.
„ 123. 6-inch telescope, by Grubb (object-glass only) to Mr. W. E. Wilson.
„ 125. 6-inch refractor by Simms, to Dr. A. A. Common.
„ 126. 3½-inch portable refractor, by Tulley, to Mr. H. Sadler.
„ 128. Bichromate battery and Ruhmkorff coil, to the Rev. W. J. B. Roome.

The Gold Medal.

The Council have awarded the Society's Gold Medal to Mr. E. E. Barnard, for his discovery of the fifth satellite of *Jupiter*, his celestial photographs, and other astronomical work. The President will lay before the Society the grounds upon which the award has been founded.

The Hannah Jackson (née Gwilt) Gift.

The Council have awarded this Gift, consisting of a bronze medal and the accumulated dividends of three years, to Mr. Lewis Swift, for his cometary discoveries and other astronomical work.

Publications of the Society.

A General Index to volumes xxx.–lii. of the *Monthly Notices* has been published during the past year, in continuation of the General Index to volumes i.–xxix., published in 1870.

Obituary.

The Council regret that they have to announce the loss by death of the following Fellows and Associates during the past year :—

Fellows :—G. P. Bidder.
Rev. Henry Collins.
T. G. E. Elger.
G. R. Farncombe.
A. H. Howe.
George Hunt.
J. H. Jones.
J. R. Jones.
Thomas Keig.
Rev. Thomas Mackereth.
S. H. Parkes.
Sir John Pender.
W. L. Sutton.
Sidney Waters.

Associates :—B. A. Gould.
Hugo Gyldén.
Adalbert Krueger.
Axel Möller.
H. A. Newton.
F. F. Tisserand.

[The names of Fellows who have died between December 31 and the date of the annual meeting are included in the above list, but omitted in the count given in the table at the commencement of the Report.]

George Parker Bidder was born 1836 August 18 in London. He was the eldest son of George Parker Bidder, C.E. (President 1860 and 1861), one of the leading engineers of the middle of the century, and known from boyhood for his powers of mental calculation. Mr. Bidder, the son, attained distinction in mathematics at the Universities, first of Edinburgh, and then of Cambridge (where he was scholar of Trinity College, and Seventh Wrangler in 1858) : he was called to the Bar at Lincoln's Inn in 1860, joining the Home Circuit. His success was very rapid, so that in 1874 he took silk, and for

the last fifteen years of his life had one of the largest practices at the Parliamentary Bar. The Forth Bridge Bills, the Tay Bridge Enquiry, and the Manchester Ship Canal Bills, are probably best known to the public among the more important cases which achieved his reputation. He was, perhaps, most sought after where it was necessary to meet a heavy array of expert evidence; this his naturally scientific mind and his mathematical training enabled him to dissect with a merciless thoroughness that discomposed all but the most candid and able witnesses. Without doubt he was greatly aided by the inheritance to some degree of the faculty of mental calculation; though by no means commensurate with that of his father, it was sufficiently above the average to give him a great advantage in tracing the various figures given in evidence to their natural, and often impossible, consequences. His mind was stored with formulæ and constants adapted to the rough estimation of quantities of all kinds, from the figures in the *Nautical Almanac* to those in a builder's estimate. The construction and testing of such formulæ, as also of purely numerical theorems, were among his favourite recreations.*

Mr. Bidder was elected Fellow of the Royal Astronomical Society on 1868 January 10, and was for many years a constant attendant at the meetings. He had a 7½-inch refractor mounted for him by Browning, and for some ten years worked seriously at the measurement of double stars. For this purpose he invented a position micrometer (described in the *Monthly Notices*, vol. xxxiv. p. 394) in which he measured with the images of the illuminated wires, the actual wires not being seen by the observer. He always afterwards used this instrument, and maintained that his measurements showed a far higher degree of accuracy with it than was possible with the ordinary form.

He wrote more than once advocating the theory that the tail of a comet is an optical effect due to lenticular action of the cometary matter on the Sun's rays, a theory in which he found he had been anticipated by a writer early in the century (see *The Times*, 1874 July 24). He was Associate of the Institution of Civil Engineers (where he obtained the Manby Premium, in 1861, for a paper on "The National Defences"), and of the Surveyors' Institution. Mr. Bidder married, in 1860, Anna, daughter of Mr. J. R. McClean, M.P., F.R.S., President of the Institution of Civil Engineers for 1864–5, and Fellow of the Royal Astronomical Society (see Obituary, for 1873), and leaves three sons and four daughters. He resided at Ravensbury Park, Mitcham, and Queen Anne's Mansions, Westminster.

Among a very wide circle of acquaintances there were few that might not have been called friends. Personally he was

* A note by Mr. Bidder on the mental calculation of logarithms will be found in a paper by Dr. W. Pole, in *Minutes of Proceedings, Inst. C.E.*, vol. ciii. p. 250.

remarkable for his strength both of body and character, allowing himself neither to be checked nor daunted by any opposition but that of his own principles, which were high and unbending. Yet he was of a tender and loving nature, and singularly light-hearted.

He died at Queen Anne's Mansions on 1896 February 1, of a clot of blood in the heart, the effects of an accident three weeks previously. He died in full success and full vigour, suddenly and painlessly.

[For the above notice the Council is indebted to his son, Mr. George P. Bidder.]

The Rev. HENRY COLLINS was born at Burslem, Staffordshire, 1830 February 16. He was vicar of Ellerton Priory, near Wheldrake, York, from 1870 June to 1888 December; and rector of Elvington, York, from the latter date till his death. He was of a nervous and retiring disposition, and devoted much time to reading. He married (1859 May 5) Mary Ann, daughter of the late Mr. William Wells, of Kenninghall, Norfolk, and leaves no issue. He died at Elvington Rectory on 1896 March 14. He was elected a Fellow of this Society on 1876 January 14.

THOMAS GWYN EMPY ELGER was born at Bedford in 1837, where the family had been established for several generations. His grandfather was Mayor of the town in 1802, and his father, an architect and builder, had three times filled that office. Thomas Elger was educated at the Bedford Grammar School, and afterwards went to University College, London, where he was a pupil of De Morgan. He adopted the profession of a civil engineer, and under Mr. (now Sir John) Fowler, he was engaged in several important works, including the Metropolitan Railway and the Severn Valley Railway. Afterwards he was engaged in surveys for railway construction in Holstein, until the work was put a stop to by the war with Prussia and Austria in 1864.

Having succeeded to his property, he relinquished the active pursuit of his profession, and devoted himself more fully to scientific studies. At an early age he had showed a strong taste for astronomy, and as a youth had constructed a telescope which served him many years later. He erected his first observatory in Caldwell Street, Bedford, where he settled with his mother. In 1880 he married, and removed to Kempston, near Bedford, where he set up an observatory in his garden, with a 4-inch refractor by Cooke, and an $8\frac{1}{2}$-inch reflector by Calver. About eight years ago he built a house in Shakespeare Road, Bedford, in which he lived till his death.

Mr. Elger's first communication to the Royal Astronomical Society, of which he was elected a Fellow on 1871 Feb. 10, was a brief note on the colours of the components of the double-star γ *Delphini*; and this was followed by observations of *Venus*, in 1873. He also gave in the *Monthly Notices* the results of a series of observations of *Saturn*, in 1887 and 1888, specially calling

attention to peculiar appearances in the crape ring, and to the varying form of the shadow of the ball upon the rings.

But it is as a careful and indefatigable selenographer that his name is best known, and for this work his artistic skill eminently qualified him. In 1878 he became a member of the Selenographical Society, a small association of observers devoted to the study of the Moon, which existed till 1882, and he contributed various papers on lunar details to its journal. He continued this work in his numerous communications to the Liverpool Astronomical Society (1882–89), and was one of the first members of the British Astronomical Association, founded in 1890. He was Director of the Lunar Section of this Association, and gave three excellent reports of the Section in 1891, 1893, and 1895, in which are digests of the work done by other observers as well as by himself. He gave results of his lunar observations in a series of articles in the *English Mechanic*, and from 1887 contributed every month to *The Observatory* a valuable chapter of selenographical notes. He was the author of the chapters on the Moon in Webb's *Celestial Objects for Common Telescopes*, and *Astronomy for Amateurs*, edited by Westwood Oliver. His most considerable work, *The Moon*, was published in 1895, and is a valuable original contribution to selenography, containing an excellent map of the Moon on a scale of 18 inches to the diameter. Most of his papers are illustrated by his own careful drawings.

Mr. Elger was an ardent archæologist, and had a fine collection of antiquities. He was one of the main supporters of the Bedford Library and the Literary Institute, and was the founder of the Bedfordshire Natural History Society and Field Club, afterwards united with the Library and Institute. His services were always at the disposal of his fellow townsmen: he was a member of numerous committees, by which his loss will be greatly felt, and, like his father and grandfather, he served as Mayor of Bedford.

He was seized with paralysis in December last, and remained in a very weak state till January 9, when he died, at the age of 59, leaving a widow and two young sons.

George Richard Farncombe, whose death occurred 1895 July 7, at Freiburg-im-Breisgau, was born at Birmingham, 1866 August 12. Being of a delicate constitution, he received a private education, and he subsequently graduated at Trinity College, Dublin (in 1884), receiving Respondent Honours. He then became articled to a firm of solicitors in Birmingham, filling up his leisure with those astronomical, meteorological, and geological studies which had early attracted him. In 1890 he came to London to prepare for his final examination in law, and threw himself heartily into the work of the numerous scientific societies of which he had long been a member. He joined and greatly enjoyed the London Geological Field Class, and in a short time Mr. Farncombe decided to relinquish the law and to devote himself entirely to geology. With this view he went to Edinburgh,

and studied for a year under Professor Geikie. Then he returned to Dublin, and worked with Professor Cole. Here his health broke down, and he was compelled to spend a winter at St. Moritz. With the return of strength he proceeded to Munich, Freiburg, Vienna, and Berlin, spending several months at each University. In 1894 September he attended the Geological Congress at Munich, and in the following November returned to Freiburg to work with Professor Steinmann. Here his knowledge and industry speedily attracted attention, and in 1895 May Mr. Farncombe was sent into Italy to undertake some survey work. There he unfortunately drank some contaminated water and contracted typhoid fever, which developed on his return, and to which he succumbed in the midst of apparent convalescence. His funeral was attended by the Rector, Senate, and Professors of the University, while every "corps" among the students sent a deputation consisting of the flag-bearer, sword-bearers, and six men. Mr. Farncombe's character was such as to secure him respect and affection wherever he went; while his great abilities, combined with a tireless industry, would have doubtless led him to a high position in his profession had his life been spared.

He was elected a Fellow of this Society on 1890 January 10.

Alexander Hamilton Howe was born at Hullerhurst, Stevenston, Ayrshire, in 1816. He was boarded in Saltcoats with Mr. Edward Gibb, parish schoolmaster of Ardrossan; next with the Rev. Mr. Roxburgh, Kilmaurs; was afterwards at Ayr Academy, Glasgow University, Edinburgh University, and finally at Paris. He was appointed to the East India Company's Civil Service; and for several years lived on the borders of Afghanistan. During the last war in that country he was attached to the reserve force. He was an excellent linguist, an enthusiastic student of astronomy and botany, and a frequent contributor to the press. In 1865 he published a book entitled, "A Theoretical Enquiry into the Physical Cause of Epidemic Diseases, accompanied with Tables," a copy of which is in the Society's library. It is devoted to proving that epidemics are caused by the effect of the Moon upon the Earth's atmosphere, and have an eighteen and a half years' period depending on the revolution of the Moon's nodes.

On his return from India he married Anne Forbes, daughter of the late Colonel Robertson, of Hallcraig, county Lanark, who survives him. He was greatly esteemed in the parish of Stevenston, where he passed the remainder of his life. He died on 1895 July 21, but the news of his death has only recently reached us.

He was elected a Fellow of this Society on 1883 January 12.

GEORGE HUNT was born at Liverpool in 1823, and, being the only survivor of four brothers, was naturally the object of great anxiety on the part of a delicate mother, who became later a confirmed invalid. After a few years at a preparatory school at Bootle, he attended the High School of the Mechanics' Institute at Liverpool, and finished his education with a private tutor. His mother's ill-health made his home life a quiet one. He took no part in active sports, and devoted himself to study. The awakening of his interest in the microscope and in astronomy was due to a neighbour, Mr. Gee. After the death of his mother he accompanied his father to Birmingham, where his uncles were engaged in ironworks and collieries. At one time they wished George Hunt to become a member of the business known as the Brades Works, at Oldbury, but after eighteen months' trial he found it so distasteful and the loss of time for his literary studies so trying that he determined to give up business. After his father's death, he spent most of his time with an uncle, who eventually made him his heir. It was then (1869) that he purchased the late Rev. W. R. Dawes's equatorial, which he erected first at Edgbaston and later at Dulwich, whither he removed three years after his marriage, in 1871. A retiring disposition prevented his taking a prominent place in the astronomical world, but his knowledge was very thorough and extensive. Among his papers are letters which show that others' estimate of his attainments far exceeded his own modest one. His illness was a short one, and his death sudden and unexpected from heart failure, after a slight attack of pneumonia, owing greatly to exhaustion from the excessive heat. He died on 1896 July 9, and was buried at Norwood. He was elected a Fellow on 1866 April 13, and in 1872 contributed to the Society a short paper "On the Identity of the Triple Star H I. 13."

JOHN HARVEY JONES was born on 1859 July 13, at Corsham, near Bath. He accompanied his father to Bristol a few years later, and assisted him in his business as a manufacturer of organs and other musical instruments. When very young he exhibited a great fondness for astronomy, and procured himself a telescope and some practical books on the science. He married in 1884 July and visited Australia, returning home in the following year and joining his father in business in Budge Street, Bristol. He first employed a $5\frac{1}{2}$-inch Gregorian telescope, but afterwards procured a $5\frac{1}{4}$-inch equatorial from Mr. Calver, which he subsequently replaced by a $8\frac{1}{2}$-inch altazimuth. He was elected a Fellow of the Royal Astronomical Society on 1888 December 14, and joined the British Astronomical Association at its formation. He became a member of the Lunar section of the latter, and furnished observations and drawings. His chief delight was in surveying the Moon and planets, and every clear night found him at his telescope, though he was not a regular contributor to the scientific journals. In 1893 he took up

meteorology, and furnished reports to the Meteorological Office for several years. He was a frequent contributor to the local newspapers, and supplied them with monthly remarks on the climatology of the district. Mr. Jones was an accomplished performer on several musical instruments, and was for some years organist at St. Nathaniel's Church, Bristol. He had also proved himself an excellent lecturer, and gave an impressive discourse on astronomy about a week before he died. Though his name was not widely known, he formed one of that numerous band of workers who love astronomy for its own sake, and who aim to contribute their little to the general progress of knowledge. A true friend, a brilliant conversationalist, and of a most agreeable and entertaining disposition, his loss is deeply deplored. He died after a few days' illness.

James Robert Jones was born at East Stonehouse, Plymouth, in 1840 October. His father was an officer in the Navy, who had seen active service and was once wounded, and who died at a comparatively early age, when the subject of this notice was very young. Mr. Jones was educated at the Free Schools at Plymouth until he was twelve years of age, and then was admitted to the Higher School at Greenwich Hospital. He displayed great aptitude in his studies, especially in astronomy and navigation. At the age of fifteen he was appointed a pupil teacher of the school. Having no taste for the sea, he was appointed assistant master in one of the schools of navigation in London under the Board of Trade, and shortly afterwards Head Master of the Navigation School at Great Yarmouth, which the Board of Trade had decided to open there. He held this appointment for seven years, during which time he married. In 1865 January, at the age of twenty-four, he was appointed Head Master of the Navigation School at Aberdeen.

Mr. Jones published several editions of a handbook on navigation for masters and mates, which was extensively used. He was an observer for the Meteorological Office, London, and for several years he compiled *Inglis' Tide Tables*, which had a large circulation in Aberdeen and district.

He was elected a Fellow of this Society on 1869 February 12. He died 1896 March 15, leaving a widow and four daughters.

Thomas Keig was born at Kirk Santon, midway between Castletown and Douglas, in the Isle of Man, in 1829. His life was spent almost exclusively in Douglas, save for a few years passed in England. It was during his sojourn in England that he attended the evening classes of Queen's College, Liverpool, devoting himself specially to the study of English literature and drawing. His first avocation was that of cabinet-maker. This he afterwards exchanged for photography. Gifted with much artistic skill, he cultivated the art of photography with great

success down to his lamented death in the spring of 1896. He left a devoted wife and family to mourn his loss.

Though ever leading an active life, and having a share in all public events in Douglas from the year 1872, he still found time in his leisure hours for deep and extensive reading in astronomy. In the autumn of 1887 Mr. Keig founded the Manx Astronomical Society. On the top of his own house he constructed an observatory. He loved to prove everything by his own research. The moon was one favourite object of his careful study. He noted down various phenomena which seemed to contradict the universally recognised theory as to the non-existence of a lunar atmosphere. He verified night after night these results. He wrote a paper describing his observations, and drawing the conclusion that the moon must have an atmosphere, which he read before the Liverpool Astronomical Society. Mr. Keig was not only the founder but the mainstay of the Manx Astronomical Society, by ever allowing his own studio to be the welcome home of their fortnightly meetings. He was elected a Fellow of this Society on 1889 February 8, and was the first resident Manxman who has enjoyed this distinction.

As a citizen of Douglas, Mr. Keig stood forth in the front rank. Again and again he was elected chairman of the Town Commissioners, and when the town was recently created a borough, Douglas could find no worthier son than Thomas Keig, F.R.A.S., to rule and guide, as first mayor, her new and enlarged destinies.

[For the above particulars the Council is indebted to the Rev. Edmund Walsh, R.C.P., of Douglas, I.M.]

The Rev. Thomas Mackereth was born at Helsington, near Kendal, on 1823 April 28. He was of humble parentage, and was apprenticed to a plumber in Manchester; but losing his parents at the age of 20, and not finding his calling congenial, he studied for and obtained an elementary schoolmaster's first-class certificate. He began a successful career as a schoolmaster in Salford, taking up his residence at Eccles in 1860, and among his pupils are a number of prominent men in South Lancashire and elsewhere. In 1878 he left the Salford School for the pastorate of the Bolton Society of the New Jerusalem Church, and held this office till 1886, when, owing to failing health, he had to retire to his native county, taking a house at Ambleside, and removing eventually to Windermere.

While at Eccles, he erected a $4\frac{1}{4}$-inch equatorial and a transit instrument, being assisted by the late Mr. Joseph Baxendell and Mr. J. B. Dancer, both his close friends. He often lectured on astronomy, and was always ready to help and encourage young students. He continued his almost nightly observations at Bolton, but there he had to leave his equatorial, as his failing health would not permit of exposure to the night air. He was elected a Fellow of this Society on 1865 March 10, and was also

a Fellow of the Royal Meteorological Society, and a regular meteorological observer. He died on 1897 January 20, after a long and weary illness, leaving a widow, one son, and three daughters.

SAMUEL HICKLING PARKES was born at Birmingham on 1817 April 8. He was the eldest son of Mr. James Parkes, of Handsworth, the founder of a firm of optical and mathematical instrument makers in St. Mary's Row, Birmingham, and joined his father in this business about the age of sixteen. He worked hard to develop this business, but always found time for scientific pursuits. He married Miss Emma Lloyd Kershaw, and they had one child, Mr. S. T. H. Parkes, who survives them. Mr. S. H. Parkes died on 1896 August 12. Among his papers was found the following note, which his son has kindly communicated to the secretaries. "A short obituary is always requested by the R.A.S. for insertion in their proceedings. If this must be, I wish it to be as brief as possible. No reference to early school days, &c., but simply spent a practical, uneventful life—early devotion to study of general science, especially natural history and comparative physiology. This pursued through life, while engaged in active business. Occasionally lecturing gratuitously on these subjects. Uniform endeavour to act under the influence of religious principles, and to employ talents and knowledge bestowed in useful ministrations to others. When unable to engage in active duties, wrote and published *Unfinished Worlds*."

It does not seem possible to comply with the spirit of this note better than by quoting it verbatim, adding simply that Mr. Parkes lived from 1865 to 1885 at King's Norton, where he had an observatory and a 5-inch refractor telescope. This was disposed of about ten years ago, and his later scientific observations were confined to microscopy. He was elected a Fellow of this Society on 1882 January 13.

SIR JOHN PENDER was born in 1815, and was the son of the late James Pender, of the Vale of Leven, Dumbartonshire. He was educated at the High School, Glasgow, and began a successful business career in Glasgow and in Manchester. His work in relieving the suffering during the Cotton Famine is still remembered with gratitude; but his chief work, which he began about the age of forty, was connected with submarine telegraphy. In 1857, when the late Mr. Cyrus Field organised the first attempt to lay an Atlantic cable, Mr. Pender was one of the contributors of 1,000*l.* towards the expenses. This attempt was unsuccessful, but the experience gained gave sufficient confidence for another in the following year, and this cable was actually laid, although it only worked for twenty-eight days. The next attempt was made in 1864, after considerable difficulty in getting the money together, and was only rendered possible ultimately by Mr. Pender offering his personal guarantee for a quarter of a million. After two-

thirds of this cable was laid by the *Great Eastern* it broke, and could not be recovered. Another company was formed to make a new attempt in 1866, Mr. Pender being again responsible for a considerable share of the expenses. This time not only was the cable successfully laid, but the end of the last year's broken cable was recovered, and it was completed. From this time Mr. Pender became a recognised leader in submarine telegraphy, and at his death presided over companies with a total capital of fifteen millions, and a cable mileage of 73,640 nautical miles. He was knighted in 1888, and promoted G.C.M.G. in 1892, and received many foreign orders and distinctions. His parliamentary career was a long and honourable one. He was M.P. for Totnes, 1865–66; Wick Burghs, 1872–85, 1892–95. He also contested Linlithgowshire 1868, Wick Burghs 1885, Stirling Burghs 1886, and Govan 1889. He took a keen interest in pictures, of which he had a fine collection, making it, moreover, a rule never to buy a modern picture without making the personal acquaintance of the artist.

He married, in 1840, Marion, daughter of Mr. James Cearns; and some years after her death he married, in 1851, Emma, daughter of Mr. Henry Denison, of Daybrook, Notts; and leaves two sons and two daughters. He was elected a Fellow of this Society on 1883 June 8. It may be mentioned that, on occasions when application has been made to the cable companies for facilities on behalf of purely scientific enterprise, Sir John Pender was always ready to use his influence in their favour, and his Fellowship of this Society was constantly referred to as one of the reasons for his doing so.

Wadham Locke Sutton was born at Highgate in 1815, and was the youngest son of the late Robert Sutton of Rossway, Hertford. His life was spent almost entirely in the neighbouring town of Northchurch, and at Dudswell, where he lived for some years, he erected an observatory containing a telescope of considerable size. He was a Master of the Mercers' Company in 1858–59. One of his chief interests was work connected with the Church, and he was rector's churchwarden from 1860 till his death, which took place at Northchurch on 1896 September 25, in his eighty-second year.

Mr. Sutton married, in 1858, Louisa Ann, daughter of the late Rev. William Ludlow, Vicar of Kirton, Lincolnshire. He was elected a Fellow of this Society on 1854 November 10.

Sidney Waters was born at Camden Town, on 1853 October 13. He was educated at Amersham Hall, near Reading, and showed considerable mathematical ability, as well as an ingenuity in devising and making apparatus. His life occupation was that of a merchant; but he was keenly interested in astronomy from an early age, and published his first paper in 1873 April, drawing attention to the fact that where "irresolvable" nebulæ cluster

there also do the "resolvables." This was stated, in the first instance, in a letter to Mr. R. A. Proctor, in conference with whom much of Mr. Waters's early astronomical work was undertaken. At the next meeting of the Society Mr. Waters (not yet quite of age) was elected a Fellow, and in the "Supplementary number" for 1873, he published the isographic charts of nebulæ and clusters on which he based the above conclusion. Recently (1894 June) he revised these charts by the help of Dr. Dreyer's New General Catalogue. He also, in 1878, gave an isographic chart of the stars in the southern hemisphere. These papers represent practically the whole of his published work, but his devotion to astronomy was shown in many ways. He went to Norway in August of the past year to observe the Total Solar Eclipse, having equipped himself with a special telescope camera. He made a very fine private collection of astrolabes; and he took a prominent part in the private business of this Society. He married in 1877 a daughter of the Rev. Edward White, and leaves a son and two daughters. Mr. Waters was grandson of the Rev. Thomas Waters and of Mr. E. Leader Williams, both of Worcester, and nephew of Mr. B. W. Leader, A.R.A., and of Sir E. Leader Williams, engineer of the Ship Canal. He died on 1896 December 14, at his residence, 44, Ladbroke Grove, W.

Benjamin Apthorp Gould was born in Boston, 1824 September 27. He entered the Boston Latin School in 1836, and graduated from Harvard College, with high distinction in classical, as well as in mathematical and physical studies, in 1844. After teaching for a year in the Latin School, he decided to devote himself to a purely scientific career. As a preparation for this he went to Europe in 1845 July, to study astronomy, working at the Greenwich Observatory three months, at the Paris Observatory four months, at the Berlin Observatory a year, at Göttingen Observatory one year, at Altona Observatory four months, and at Gotha Observatory one month. He returned home in 1848. In 1852 he was appointed to take charge of the longitude determinations of the Coast Survey. He organised, developed and extended this service, retiring in 1867. Meanwhile, in 1855, he became Director of the Dudley Observatory, in Albany, equipped and organised the institution, and carried it on without remuneration and at his private expense. He left it in 1859, after a severe struggle to preserve the institution for purposes of scientific investigation.

In 1859 he published his discussion of the places and proper motions of circumpolar stars for use as standards in the Coast Survey. These, as revised by him in 1861, together with his similar list of clock-stars, were adopted as the standards for the American ephemeris, and, as to the circumpolars, remain in such use to this day. In 1866 he published his reduction of d'Agelet's observations. About the same time he performed a similar service for the greater part of the observations made at the

United States Naval Observatory since its establishment, and also for the expedition to Chili to determine the solar parallax. In 1866 he planned and executed the work of establishing, by the Atlantic cable, the relation in longitude between European and American stations. As actuary of the United States Sanitary Commission he conducted, and published in a large volume, extensive and important researches upon Military and Anthropological Statistics and the Distribution of Population. About the same time he undertook the reduction of Rutherfurd's photographs of the *Pleiades*. The results, partially published in 1866, were submitted completely, in a elaborate memoir, to the National Academy in 1870, together with a second memoir on the *Præsepe*. He was, indeed, a pioneer in the utilisation of photography for exact astronomical measurement. About 1864 he built an observatory in Cambridge, equipped with an 8-foot transit-instrument, and, until 1867, carried on a determination of the right ascensions of all the stars to the tenth magnitude within one degree of the pole. This work was completely reduced, but the discussion and publication were postponed by his removal to Cordoba.

In 1865 he became intensely impressed with a desire to explore the southern celestial hemisphere. The opportunity to do so soon came. This project assumed at first the form of a private astronomical expedition, for which his friends in Boston had promised the pecuniary means; but, under the enthusiastic support of Mr. Sarmiento, at first as Argentine Minister to this country, and later as President of that Republic, it rapidly broadened, and finally led to the establishment by Dr. Gould of a permanent National Observatory at Cordoba. This important addition to the observatories of the Southern hemisphere, which are comparatively so few, forms an impressive monument to his memory.

It is impossible, in brief space, to describe or characterise the marvellous work here undertaken and so faultlessly pushed to completion by Dr. Gould, during the fifteen years of self-imposed exile from his native land, with unfaltering devotion and energy, in the face of difficulty and domestic bereavement. The work on the uranography of the southern heavens was finished in 1874, and was published under the title of the *Uranometria Argentina*, which will remain a classic for all time. For this work he received the Gold Medal of this Society in 1883, and in presenting it, the President remarked that, great and important as the work was, it was still but a small, and in his opinion, not the most valuable part of that which Dr. Gould had done at Cordoba. The zone observations of the stars between 23° and 80° south declination, which were the original and always the dominant object of the enterprise, were begun in 1872, substantially completed in 1877, and revised in 1882–83. This work was embodied in the Zone Catalogues containing 73,160 stars, which appeared in 1884. Parallel with this, and almost overshadowing it in importance, was

carried on the independent series of meridian-circle observations for the General Catalogue of 32,448 stars, completed in 1885. Dr. Gould, besides, left the manuscript of the remainder of his series of fifteen volumes, not then published—containing the observations and the annual catalogues, incorporated in the General Catalogue—complete to the minutest detail ready for the printer. These have since appeared from time to time—the last volume, rounding off his work, reaching Cambridge but a few hours before his death.

Another part of the work for the Cordoba Observatory, planned by Dr. Gould as a fitting extension of it, was a *Durchmusterung* of the southern sky. For this, indeed, he had provided the instrumental means and trained the assistants, it being his purpose to be ready to begin it at any time in case of unforeseen delay or accident to the other work. On leaving Cordoba he confided it to the care of Dr. Thome and Mr. Tucker, who have since so worthily conducted it.

Dr. Gould also established, under the auspices of the Argentine Government, a meteorological service, second in extent, it is believed, only to that of the United States. Upon leaving South America he intrusted this charge to the hands of his worthy successor, Walter G. Davis.

The earliest to realise and demonstrate the capabilities of photography to render service to the astronomy of precision, Dr. Gould, by his experience with the Rutherfurd plates of the *Pleiades* and the *Præsepe*, was incited to arrange to carry forward at Cordoba, on an extensive scale, a similar work upon the southern stellar clusters. His other labours there were so onerous that he confined his attention to securing plates suitable for precise measurement. Of these he accumulated about 1,400, and brought them home with him in 1885 for measurement and reduction. Without permitting himself a well-earned retirement, he turned at once tirelessly to this labour, which has been the principal occupation of the last ten years of his life. This is substantially complete, so that it will be given to the world as it came from his hand. That he might be spared to do this was his most earnest solicitude and hope.

Dr. Gould had, as we have already remarked, an enthusiasm for his beloved science far wider than the limits of what he could accomplish by personal investigation. Early in his career he had realised that astronomy had reached a stage of development in America which entitled it to a higher claim than had yet been accorded to it, and that a journal worthily supporting the dignity of a pure science would have very great influence upon its future progress. Accordingly, without ostentation, he established the *Astronomical Journal* in 1849, offering it to the use of astronomers, for the publication exclusively of original investigations. He edited and supported it until, at the end of the sixth volume in 1861, its issue was suspended, first by the war for the preservation of the Union, afterward by his absence in

Cordoba. A long-nurtured hope was realised when he was enabled in 1885 to resume its publication, and to continue it at the rate of nearly one volume annually to the present time. With careful forethought he has made due provision for its continuance.

Considered apart from the great things he accomplished, the first point that strikes us in Dr. Gould's career is the intimate way in which it is bound up with the history of his beloved science on both sides of the Atlantic, and the unique position he held, as illustrated by the number and extent of his personal alliances. It is scarcely possible to realise that he was the friend of Von Humboldt, then in his seventy-seventh year; that it was due to the friendly interest of this great man indeed that he became the pupil, friend, and intimate in the household of the great master of modern astronomy, Gauss, then in his seventieth year; that he was a pupil of the illustrious Encke, of the elder Struve, of Hansen, of Peters and Argelander, and the life-long friend of these and other revered men, the pillars of the science. His correspondence with them after he returned to his native land testifies to the mutual confidence that characterised these memorable associations. Following these in the next generation come Winnecke, Schönfeld, Auwers, and a numerous host besides, which to us are great names, but to Gould were fellow-pupils and associates. Of the same epoch, in America, we have Bache, Peirce, Walker, Hubbard, Coffin, Chauvenet, and Winlock. Then come the two living generations of astronomers, bringing friendships and acquaintances wide as the world itself, extending his relations to the youngest workers in the science. With such universal and intimate connection with the personal forces operating to advance astronomy in all lands, with his intense patriotism, with his strong intellectual and moral traits, he could not fail to exercise a powerful moulding influence upon the development of American astronomy. It was to this end, in preference to the satisfaction of ambition through what he could achieve by his personal contributions to the fund of knowledge, that his most earnest efforts from the beginning of his career were directed. In one of his letters to Von Humboldt, in 1850, after speaking of the dependent condition at that time of science in America, its self-distrust and intellectual timidity, he says: "This I knew before returning home, but realise it now, for the first time, to its full extent. Therefore it is that I dedicate my whole efforts, not to the attainment of any reputation for myself, but to serving to the utmost of my ability the science of my country —or, rather, as my friend Mr. Agassiz tells me I must say, science in my country." And to Encke he says, speaking of the establishment of the *Astronomical Journal*, and his fond hopes in its agency as a means of raising the astronomy of America to its proper position: "Though the labour of supporting it will prevent me from working as I otherwise should for the advancement of my own reputation, still the consciousness that I may render now

a still greater service to science reconciles me to the abandonment of a good deal of personal ambition." The same spirit breathes throughout his correspondence with Gauss, Schumacher, and other great leaders abroad, to whom he was wont to confide his projects and aspirations, and who sympathised with and counselled him in return. His letter-books are rich with similar illustrations.

And this brings us to another remarkable point about Dr. Gould's career. If we were asked to place the finger upon the epoch marking the birth, or regeneration, of American astronomy, we should feel inclined to name the date 1845 July, when Gould placed his foot upon the steamer from Boston with the avowed and definite purpose to devote himself to a life purely of scientific research. Up to that time the instance of a man doing this as his only earthly aim, while unassured of a professor's chair or similar appointment, and not as a means of livelihood, was in America absolutely unknown.

He inspired a new breath into American astronomy. The new atmosphere which he brought with him from Germany, where he caught the spirit of the great masters under whom he studied, became gradually transfused through the States. His enthusiasm for the introduction of better means and methods of research was caught by his compatriots, their courage in the effort to regenerate our science was sustained, and transmitted through various channels to the next and to the present generation.

Dr. Gould married, in 1861, Mary Apthorp Quincy, daughter of Hon. Josiah Quincy. She died in 1883. Her sympathy with and influence upon his life work may be most reverently spoken of by recalling the affecting lines of his dedication of the great Zone Catalogues: "This Catalogue of Southern Stars, the fruit of nearly thirteen years of assiduous toil, is dedicated to the beloved and honoured memory of Mary Apthorp Quincy Gould, to whose approval and unselfish encouragement the original undertaking was due, by whose sympathy, self-sacrifice, and practical assistance its execution was made possible, who bravely endured privation, exile, and afflictive bereavement that it might be worthily finished, but who has not seen its completion."

Dr. Gould received the degree of Ph.D. from Göttingen in 1848, and that of LL.D. from Harvard in 1885, and from Columbia in 1887. He was For. Mem. Roy. Soc. (London); For. Assoc. Roy. Astr. Soc. (London); Cor. Mem. Acad. Sci. (Institut de France); Acad. Imp Sci. (St. Petersburg); Kön. Akad. Wiss. (Berlin); Kön. Ges. Wiss. (Göttingen); Kais. Akad. Wiss. (Vienna); Bur. d. Long. (Paris). He also received the order Pour le Mérite from Prussia..

[For the above notice the Council is indebted to Mr. S. C. Chandler.]

Hugo Gyldén was born in Helsingfors, Finland, on 1841 May 29. The only son of his parents, he received from them the

most careful nurture and education, which in his case brought a rich reward. After completing his university course, he went to Gotha, in 1861, that he might obtain from the illustrious author of the *Fundamenta Nova*, *Perturbations qu'éprouvent les Comètes*, *Zweckmässigen Methode die Störungen der kleinen Planeten zu ermitteln*, &c., a thorough acquaintance with the (then new) methods of the theory of perturbations. In 1862 he returned to Helsingfors to practise at the University as *docent*, but he soon left for Pulkowa, where he worked hard in the observatory till 1871. In that year he was called to Stockholm, being appointed Director of the Observatory of the Academy of Sciences; and this position he held till his death on 1896 November 9, in spite of flattering invitations to undertake the direction of other observatories—Helsingfors, Gotha, Göttingen, &c.

It is always of interest to study the history of a great man's work. In the case of Gyldén it is remarkable how, in spite of its diversity, a fundamental connection can be traced throughout. If we specially consider his researches on the groundwork of planetary theory, the logical order of the development is at once apparent. The methods of Hansen are devised especially to simplify numerical calculations in order to lighten the mechanical work in studying celestial motions. Gyldén's work in the first period bears traces of Hansen's influence—defining as the first period that in which he endeavoured to simplify the calculation of perturbations on familiar lines. The one investigation dealt with minor planets, the other with comets, the two together representing an attempt to simplify the problems of motion in orbits of moderate and large eccentricity. The valuable series of publications which resulted from these two inquiries is well known to astronomers. He treated the second most completely, and was thus led to complex mathematical researches, preparatory to the second period.

The unsatisfactory nature of methods hitherto known, all based on the Keplerian ellipse, had long ago attracted Gyldén's attention, and in the course of the above-mentioned investigations he devised the means of attacking the fundamental problem of the theory, the absolute orbits of the planets. The second period, which occupied the last 16 years of his life, was devoted to this problem. The principal results as yet published are the memoirs *Ueber die Convergenz*, &c., the *Nouvelles Recherches*, and the *Théorie des Orbites absolues*, vol. i. Of this last work vols. ii. and iii. are still to come. In the same connection Gyldén undertook an investigation on the planet *Hilda* and the satellite *Hyperion*, which are known to have analogous motions. To give details of this work here would take too long.

This is a brief indication of Gyldén's chief work, but his catholic genius did excellent work in other departments of astronomy. His researches on the rotation of the Earth and on stellar parallax are well known to astronomers. During his stay

at Pulkowa he was charged with the vertical circle to determine the declinations of the Pulkowa fundamental stars, and this led to his devoting attention to various questions of stellar astronomy. A man of his stamp could not be satisfied with merely making the observations, which he regarded as merely the starting-point for real astronomical work. He undertook a discussion of the theory of refraction, which forms the basis of the Pulkowa refraction tables. His memoir in the fifth volume of the Pulkowa observations gives a faithful picture of him as a practical astronomer. Finally, to give some idea of his versatility, we may mention the regions in which he did and published work of more or less importance: the theory of the motions of planets and comets, mathematical analysis, the problem of rotation, stellar parallax and proper motion, theory of refraction, variable stars, cosmogony, popular astronomy, biography, philosophy. The number of his published works and memoirs exceeds 200.

The astronomical world will mourn Gyldén's death, not only because a distinguished man of science of whom much might yet be expected has been cut off in the prime of life, but also because he has been snatched away from his most important researches on planetary motion just as he was about to gather the ripe fruits of his labours. This refers more especially to the second and third parts of his *Théorie des Orbites absolues*, and to the application of his methods to special cases of motions of the minor planets and satellites, for it was here that we might look for the most important results of his work in revising the theory of planetary motion. Although it is believed that he has left the work in MS. so nearly complete that it can be edited and published with comparatively little trouble, still it can no longer come from his own hands, and herein lies the bitter sadness of Gyldén's early death. On the other hand, it may be stated with confidence that the method of investigation in the planetary theory initiated by Gyldén has been established on a firm and permanent footing. For this no better testimony is needed than the number and names of those who have studied Gyldén's theory. That which he strove for he in the main accomplished, and the accomplishment required not only all his skill, but all his own great energy.

Gyldén possessed in the highest degree those qualities which make a scholar in the true sense of the word. His lofty conception of science and its aims was an inspiration to those who had the good fortune to be intimate with him; personal intercourse with him was a perfect stimulus towards scientific activity.

[For the above notice the Council is indebted to Dr. O. Backlund, Director of the Pulkowa Observatory.]

Carl Nicolaus Adalbert Krueger was born on 1832 December 3 at Marienburg, in West Prussia. He was at school, first at Elbing, and later at Wittenberg. In 1851 he entered the Berlin University to study mathematics and science, and soon

showed an especial preference for astronomy. But he did not devote himself exclusively to it until 1853, when he left Berlin for Bonn, and found in Argelander a master who understood better than all others how to inspire his pupils with a love of astronomy. Argelander soon remarked the ability and energy of his young pupil, who was not deterred by any amount of labour, and even before he took his Doctor's degree in 1854 August (for which his dissertation was "De ascensionibus rectis a Flamsteedio quadrantis muralis ope observatis"), appointed him, in the autumn of 1853, Second Assistant at the Bonn Observatory. He thus shared with Schönfeld the work on the recently undertaken Durchmusterung of the northern heavens, a task which called for all the energies of the workers if it was to be completed within a moderate time. It was finished in six years, and the results are published in vols. iii.–v. of the *Bonn Observations*. But Krueger showed himself a true pupil of Argelander, in that even this heavy work did not exhaust his activities. So far as it allowed, he observed comets and planets with the ring micrometer, variable stars, and computed numerous cometary and planetary orbits, especially that of the planet *Themis*, which he made his own particular care without intermission till his death. Two memoirs on the orbit of *Themis* appeared in 1866 and 1873 in the *Transactions of the Society of Finland*. A third memoir was projected, but unfortunately not completed. He also determined stellar parallaxes with the heliometer, especially those of 70 *Ophiuchi*, *Lalande* 21258, and *Arg. Oeltz.* 17415-6, and his triangulation of the cluster *h Persei* has been a pattern for other subsequent workers in the same field.

He was appointed First Assistant in 1859, and qualified as Privatdocent in the University in 1860. But in 1862 June he was called to Helsingfors as Professor of Astronomy and Director of the Observatory, which his honoured master, Argelander, had founded and directed until his appointment at Bonn. Here he selected for special attention the meridian circle, although observations of comets with the refractor were not neglected. His plan was to reobserve the stars of the Abo Catalogue, and to make special observations in conjunction with Argelander, but both projects were superseded by the zone observations for the *Astronomische Gesellschaft*, Krueger being one of the first to give in his adherence to the scheme. The 8-foot transit instrument seemed to him more suitable for the observation of his zone ($+55°$ to $+65°$) than the smaller circle, and he read the declinations on an auxiliary circle. The work was conducted with characteristic energy; the first zone was observed on 1869 August 30, and in 1876, when Krueger left Helsingfors, more than two-thirds of the whole was completed.

Besides observational work, Krueger found time at Helsingfors for considerable literary activity. First he reduced and published the Bonn heliometer observations, then he was continually busy with the orbit of *Themis*; and to this epoch (1868)

belongs the computation of the orbit of Comet 1785 II, which was interesting as having elements somewhat resembling those of Comet 1867 III. His idea (1864) for the barometer compensation of a pendulum, by using an imperfect vacuum, was an important step in practical astronomy. His publication of the observations of the Helsingfors Magnetic and Meteorological Observatory from 1845–56, during which period the thermometer was read every twenty minutes, afforded an opportunity for a complete discussion of the mean temperature of Helsingfors, which appeared in 1874.

In 1876, on Hansen's death, Krueger was appointed Director of the Gotha Observatory. Had this promotion meant the interruption of the zone observations, he might have hesitated to accept it; but the Helsingfors University authorities generously lent the transit instrument to the Gotha Observatory for some years. Here he recommenced his work on 1877 July 31, after re-erecting the meridian piers. His completion of it was simultaneous with his leaving Gotha in 1880; and the few necessary revision observations were made by Donner at Helsingfors after the return of the instrument.

We come now to the last period of Krueger's life, during which he was Director of the Kiel Observatory and Editor of the *Astronomische Nachrichten*. It was not without many searchings of heart that he undertook these duties; but a mere glance at the forty volumes which appeared with his name on the title-page is sufficient to show that he was the right man in the right place. As soon as his editorial duties allowed him, he proceeded with the final discussion of his zone observations, which were published by the Helsingfors University in two volumes (1883 and 1885). Astronomers were thus able to judge of the quality of the work long before the appearance of the final Catalogue of 14,680 Stars, which was published by the *Astronomische Gesellschaft* in 1890.

In 1882 Krueger, as Editor of the *Astr. Nach.*, was appointed Director of the new "Centralstelle für Astr. Telegramme," and performed his new duties with the greatest zeal. He made it a point that the elements and ephemerides of the newly discovered comets should appear in the *Astr. Nach.* at the earliest possible moment, and computed not a few of them himself.

About the year 1889 an affection of the heart declared itself, and from the autumn of 1895 this and other complications made his illness assume a serious character, which was soon seen to be hopeless. He lingered some six months in great pain, and died on 1896 April 21.

Krueger was elected a Foreign Associate of this Society on 1879 January 10. Many other learned societies conferred similar honours upon him, especially the Finnische Societät, the Sächsische Ges. der Wiss., and the Berlin Akademie. He married a daughter of his master, Argelander, and had one daughter.

[His son-in-law, Dr. H. Kreutz, has kindly abridged this

notice from his somewhat longer account in the *Vierteljahrsschrift der Ast. Gesell.*]

DIDRIK MAGNUS AXEL MÖLLER, the son of a civil officer in the province of Schonen, in South Sweden, was born 1830 February 16. He shewed mathematical ability of a high order almost from infancy, and entered the Lund University at an exceptionally early age. On passing his examination in 1853 he was immediately nominated Docent, in 1855 he was made an Observer, in 1861 Extraordinary Professor, and in 1863 Ordinary Professor. His predecessor in the chair was much occupied with public matters. Möller had practically undertaken the professorial work from the time he was appointed Docent, with the exception of a period in the years 1858–59, during which he travelled in mid-Europe with the object of adding to his scientific knowledge, a short time spent in visiting Pulkowa in 1861, and a few weeks in the summer of 1860, when he took part in the solar eclipse expedition to Spain.

In the years which followed Möller was on several commissions for the remodelling of the higher grade educational institutions of Sweden. His interest in all educational matters was very keen, and his opinion always commanded the greatest respect. For a long time he was Rector of his University, and would have held this office till his death but for his own wishes, which caused his resignation in 1895. Long after the conclusion of his duties as teacher he continued to superintend the final examinations of the students. His ability further shewed itself in various matters of administration, where his sound common sense and financial knowledge were of the greatest value. His fine constitution resisted the hardships and fatigues of a hard-working observer's life for many years; but in the spring of 1896, during a journey in North Sweden, he caught a severe cold. This left behind an affection of the heart which put a sudden end to his busy life on 1896 October 25.

Möller's scientific work began in 1853 with a determination of the longitude of Lund, after which he undertook the determination of the orbit of Comet 1852 III. Then the peculiarities of the orbit of Faye's Comet absorbed his attention; from 1860 onwards he undertook a long series of investigations on this subject, and by extraordinary care and completeness in his work he finally succeeded in determining the orbit with extreme precision, and gave ephemerides for the returns in 1865, 1873, and 1880–81 with a success which is well known. From the first this work attracted the notice of the astronomical world, and practical recognitions of its value came from various quarters. In his honour the Comet has been named Faye-Möller; and he was awarded the Gold Medal of this Society in 1881. In presenting the medal, the President, Mr. J. R. Hind, who was well qualified to speak with authority on the occasion, reminded the Society that the class of computation involved in such investigations is

of a high order, and "does not admit, as is often the case with heavy masses of astronomical calculations, of being set out for the ordinary computer. Considerable mathematical knowledge, and knowledge of refined methods, and of their adaptability to particular cases, is absolutely essential; and Professor Möller's success has proved that he possesses this knowledge in an eminent degree."

Another member of our system which occupied Professor Möller's attention was the minor planet *Pandora*, the perturbations of which he calculated by Hansen's method. Many minor investigations appear in the publications of the Lund University, and it is to be remembered that the observatory itself wherein these observations were made is due to Möller. At the time of his appointment as Professor the Lund University only possessed a few very ordinary astronomical instruments; but as a result of his strong and urgent representations the University built a new observatory and equipped it very completely. In this Möller worked zealously for many years, making numerous observations, especially of planets. He was an indefatigable worker. Whatever he undertook he carried through to the end with all his energies. His loss will be severely felt by all who knew him and had felt the influence of his strong and upright character.

[For this notice the Council is indebted to Dr. Folke Engström.]

Hubert Anson Newton was born on 1830 March 19, at Sherburne, in the central part of New York State, the fifth son of a family of seven sons and four daughters, children of William and Lois Butler Newton. Both parents, who traced back an ancestry to the first settlers of Connecticut, had migrated westwards and settled on a large farm which yet remains in the family. William Newton was a man of considerable enterprise, and undertook the construction of the Buffalo section of the Erie Canal; his wife was famed for her mathematical powers among her near acquaintance, so that the natal gifts to this one of their children are clearly manifest.

Young Newton fitted for college at the schools of Sherburne, giving early promise of mathematical taste. He entered Yale at the early age of sixteen, in the class graduating in 1850. In the college records he appears as a speaker at the junior exhibition of his class, with "India" as his theme, and in the graduation list he won an "oration" stand, though his name is not on the list of commencement speakers. More significant of his gift was the winning of the first prize for the solution of mathematical problems.

After graduation he pursued his studies; was appointed tutor at Yale in 1852, taking full charge of the department of mathematics during the illness of the senior professor at that time; and in 1855 he was elected full professor at the early age of twenty-

five, probably the youngest graduate of the college to reach that honour.

Entering upon this charge after a year's study in Europe, he filled it with signal success until his death, which occurred in New Haven, on 1896 August 12, being then the senior professor as regards length of service in the college. His life was outwardly uneventful, passing away quietly in the duties of his chair, with occasional trips to Europe.

His efforts in the cause of education were shown in many ways, amongst others in the securing of an adequate presentation of the metric system in the school arithmetics of the United States. His contributions to science were in part in pure mathematics, dealing mainly with the analysis of curves; but his name will be chiefly connected with his researches on meteors and comets, a brief enumeration of the most important of which will not be out of place here.

Professor Newton's papers on meteors began to appear in 1860, and dealt at first with a few special cases of observed fireballs; he soon, however, attacked the subject on broader lines. In 1864 he published his well-known discussion of all the original records of the November star shower, finding evidence of thirteen showers since A.D. 902, and showing clearly the existence of the cycle of thirty-three and a quarter years. Considering the phenomenon to be caused by a closed ring of meteoroids revolving around the Sun, he made it clear that the period must have one of five values, ranging from a little less than half a year to the thirty-three and a quarter years of the cycle. He inclined toward one of a little less than one year, but pointed out the test supplied by the variation of the node he had found to amount to $1''.7$ annually, of which only one half is caused by precession, and the rest must be due to planetary perturbations. As will be remembered, Professor Adams carried out this test, and showed that the long thirty-three and a quarter year period alone gave the correct nodal displacement. The complete verification of Newton's prediction of a large display of meteors on 1866 November 13 is also a familiar matter of history, together with the identification of the orbit of the meteoroids then seen with that of the comet which preceded them about a year.

Meanwhile, in 1865 March, Professor Newton had published a memoir in which from a large number of observations of sporadic meteors he derived their numbers, their frequency in the space traversed by the Earth, their velocity and the conclusion that their orbits resemble those of comets, thus, doubtless, paving the way for the now generally accepted theory of meteors. He also organised parties for the observation of the expected shower, and deduced the relative numbers of shooting stars seen by various numbers of observers.

In 1875, in a paper on the "Origin of Comets," he took up the question as to whether the comets originated from matter in stellar space extraneous to the solar system or formed part of the

primeval solar nebula. Arguing from the distribution of their orbits, he finds that both aphelia and inclinations point to an origin foreign to our solar system. In connection with this he discussed the effect of large planetary perturbations of the planets on the distribution of cometary orbits, a subject he recurred to subsequently in 1891, in a memoir on the "Capture of Comets by Planets, especially *Jupiter*." In this he showed that of 1,000,000,000 comets coming inside *Jupiter's* orbit with parabolic velocity 126, 839, 1,701, and 2,670 will respectively be so retarded by *Jupiter* as to have periods respectively less than $\frac{1}{2}$, 1, $1\frac{1}{2}$, and 2 times that of *Jupiter*.

The Biela meteors of 1885 led him to express his view that these, together with those seen in 1872, must have left the neighbourhood of the parent comet about 1841 or 1842, and in order to account for the rapid disintegration and dispersion, he thought the various particles might have been subject to a varying attraction of the Sun, somewhat in the manner observed in the repellent forces by which the cometary tails are caused.

Professor Newton's last considerable contribution to meteoric science was on the orbits of those meteorites or stones which are in our cabinets, and which were seen to fall. From 265 observed falls, of which 210 only gave the hour and 116 gave the direction also, he found that all but 7 of the 116 moved in orbits having direct motion, and their perihelion distances in general were less than the Earth's radius. At the time of his death he was engaged in editing a collection of a large number of meteor-orbit determinations, mainly observed in America; and it is hoped that this work may be brought out before long.

These investigations, together with numerous smaller ones, did not fail to command the attention and respect of his fellow-scientists, and received both at home and abroad deserved recognition. Professor Newton was one of the original members appointed by Congress to constitute the National Academy of Sciences; was vice-president of the mathematical section of the American Association for the Advancement of Science in 1875, when his retiring address took the form of a strong plea for more study of mathematics by men of science; and president of the Association in 1885, when his presidential address was a synopsis of meteoric lore up to that date. In 1872 he was elected an Associate of the Royal Astronomical Society, in 1886 an Honorary Fellow of the Royal Society of Edinburgh, and in 1892 a Foreign Member of the Royal Society of London.

Professor Newton was deeply interested in the welfare and development of his *alma mater*, and had great influence in the councils of the college and university. The Yale Observatory, when organised in 1882, was placed under his direction, and although he nominally resigned the directorship in 1884, the institution remained under his charge, and may be said to owe its existence to his untiring efforts and personal sacrifices in its behalf.

In personality Professor Newton was most gracious and kindly, and in all things simplicity itself. He was tireless in his efforts to aid poor students at Yale in securing an education, and not a few have owed to him the means of their college careers He also found time from his numerous duties to devote to the political service of his co-citizens, and served as alderman in the New Haven City council.

Professor Newton married in 1859 Anna C., daughter of the Rev. Joseph C. Stiles, of Georgia. She survived him but three months, leaving two daughters.

FRANÇOIS-FÉLIX TISSERAND est né à Nuits-Saint-Georges, dans le département de la Côte-d'Or, le 13 janvier 1845. Après de bonnes études littéraires il entra, en 1863, à l'Ecole normale supérieure. Le directeur se plaisait, dans les comptes rendus annuels des travaux de l'école, à signaler l'élève Tisserand à ses camarades comme leur donnant tous les bons exemples : à un talent qu'on pressentait Tisserand alliait une modestie rare et le sentiment du devoir.

Sur l'offre de Le Verrier, Tisserand entra, en 1866, comme astronome adjoint à l'Observatoire de Paris. Il fit successivement partie du service méridien, du service géodésique, dont Villarceau était chef, et de celui des équatoriaux. Une thèse consacrée à l'exposition, d'après les principes de Jacobi, de la méthode suivie par Delaunay dans sa théorie du mouvement de la Lune marqua brillamment les débuts scientifiques de Tisserand, qui, peu après, partait en compagnie de MM. Stephan et Rayet pour aller observer sur les rivages de la presqu'île de Malacca la fameuse éclipse de Soleil du 18 août 1868.

Tisserand n'avait que 28 ans quand il fut envoyé à Toulouse pour y réorganiser l'observatoire. Il s'acquitta de cette tâche avec une rare distinction. Les ressources étaient modestes et le personnel faisait défaut. Tisserand devina la vocation astronomique de MM. Perrotin et Bigourdan, qu'il sut s'attacher. Il institua des observations aussi importantes que variées sur les satellites de *Jupiter* et de *Saturne*, les étoiles filantes, les tâches du Soleil ; plusieurs petites planètes furent découvertes.

En 1878 Tisserand recueille la succession de Le Verrier à l'Académie des Sciences ; la même année il entre au Bureau des Longitudes et est appelé à suppléer Liouville à la Sorbonne. A partir de 1883, il occupe la chaire de Mécanique Céleste, d'abord comme suppléant, puis comme successeur de V. Puiseux. Ses obligations de professeur ne l'empêchèrent pas d'aller observer, en 1882, à la Martinique, avec MM. Bigourdan et Puiseux, le passage de *Vénus* sur de Soleil ; le même phénomène l'avait amené, en 1874, au Japon, avec M. Janssen.

C'est à partir de 1883 que Tisserand prit vraiment possession de lui-même. Le devoir, qui s'accordait avec son goût, de parcourir le cycle entier de la mécanique céleste allait le pousser à l'exécution d'un grand ouvrage, Le *Traité de Mécanique Céleste*,

dont l'objet a été de coordonner toutes les recherches, de faciliter la lecture des mémoires originaux, en somme, d'exposer les progrès accomplis depuis Laplace. Plusieurs parties de la science ont été enrichies par lui de conclusions souvent très importantes, toujours nettes et élégantes. Ses recherches sur la forme générale des expressions des perturbations, sur le rôle des petits diviseurs et la libration des petites planètes se rattachent à sa thèse de docteur. Tisserand a toujours estimé que la théorie de la variation des arbitraires de Lagrange, dont la méthode de Delaunay procède, suffisait pour aborder les questions les plus hautes. Quelques feuillets provenant de leçons de l'incomparable professeur V. Puiseux sur cette théorie constituaient, Tisserand aimait à le redire, son meilleur instrument de travail. Les calculs, il est vrai, sont souvent compliqués ; mais les calculs algébriques ou même numériques n'effrayaient pas Tisserand, qui les conduisait jusqu'au terme avec une sûreté extraordinaire.

L'article du *Bulletin Astronomique* (1889) "Sur la Théorie de la Capture des Comètes Périodiques," a été l'un des plus goûtés par les astronomes, et le *critérium* qui permet de reconnaître si des comètes font ou non partie de la même famille est maintenant connu de tous. C'est la lecture de l'ouvrage élémentaire *General Astronomy* de M. Young qui engagea Tisserand à examiner d'une manière plus précise cette théorie de la capture des comètes. On peut rapprocher ce beau morceau des notices admirables de simplicité et de justesse parues dans *l'Annuaire du Bureau des Longitudes*. Ces notices très étudiées se trouvent réunies pour la plupart à la fin de la *Cosmographie*, publiée avec M. Andoyer.

Les théories des satellites l'ont surtout captivé. Le tome iv. de son *Traité de Mécanique Céleste* montre toute la part qui lui revient dans ces études si intéressantes, où le géomètre rencontre, sans être condamné à des calculs rebutants, les circonstances les plus variées jusqu'à la difficulté grave entre toutes d'un extrême rapprochement des corps en présence. Il avait attiré, l'un des premiers, l'attention des astronomes sur les particularités du système de *Titan-Hypérion* (*The Observatory*, t. iii). Il mit en évidence, par la seule puissance du calcul, l'aplatissement de *Neptune* que les lunettes ne pourraient déceler.

Il n'est pas possible de passer sous silence une œuvre à laquelle Tisserand a donné beaucoup de son temps : le *Bulletin Astronomique*. Pour lui ce n'était pas seulement un instrument utile de travail, mais encore un moyen d'activer le mouvement astronomique. En rapprochant les derniers volumes de la collection des premiers, on peut juger de la transformation féconde de l'esprit de Tisserand. Son autorité de savant s'affermit, et en même temps la souplesse, l'étendue de son esprit s'accusent toujours plus. C'est ainsi qu'il est question à la fois dans le seul volume de 1895 : des étoiles filantes ; du nouveau satellite de *Jupiter* ; du calcul des orbites circulaires ; d'une inégalitée à longue période de l'étoile variable *Algol*, dont la cause est rattachée à l'aplatissement de l'étoile principale ; de la vitesse

radiale des nébuleuses ; du mouvement propre du Soleil ; enfin de la libration des petites planètes.

La nomination de Tisserand à la direction de l'Observatoire de Paris, après la mort inattendue du regretté amiral Mouchez, en 1892, lui traça de nouveaux devoirs. Sans doute il avait à cœur de mener à bien l'œuvre principale de son existence de savant ; mais il ne négligea pour cela aucun détail de l'administration de l'établissement. Il sut trouver temps pour tout en mettant chaque chose à sa place. Quel guide précieux on aurait eu en lui alors que satisfait d'avoir achevé son traité il aurait donné le meilleur de lui-même aux questions d'astronomie pratique ! Son étude toute récente des variations de la pendule normale causées par les variations du baromètre marquait un premier essai dans cette voie. Il n'a pas été, comme son prédécesseur, l'homme des initiatives hardies, mais dans quelle mesure il a contribué comme président du Comité de la Carte photographique du Ciel, par sa direction, en même temps si bienveillante et si ferme, à aplanir les difficultés, à assurer le succès de la grande entreprise scientifique de l'amiral Mouchez ! Ce fut pour lui une joie profonde que de recevoir les témoignages d'estime de tous les astronomes réunis, à Paris, au mois de mai dernier, à l'occasion du Congrès astrophotographique.

Peu de mois après, dans la nuit du 20 octobre, Tisserand était enlevé subitement à l'affection de sa famille, de ses amis et de ses élèves, à l'estime profonde de tous. Rarement autour d'un cercueil put-on voir une pareille unanimité de regrets. C'est que Tisserand avait reçu en don, à un degré éminent, les qualités du génie français : la clarté, l'élégance, la justesse, le bon sens ; en même temps on pleurait la disparition d'un homme droit, guidé par les principes d'équité et de justice, simple et modeste comme au début de sa carrière, naturellement bon, désireux de tout concilier, plein de sollicitude pour les jeunes gens débutant dans la carrière scientifique. O. CALLANDREAU.

[For the above notice the Council is indebted to M. O. Callandreau.]

Proceedings of Observatories.

The following reports of the proceedings of observatories during the past year have been received from the Directors of the several observatories, who are alone responsible for the same :—

Royal Observatory, Greenwich.

With the transit circle 12,456 observations of transits and 10,856 of meridian zenith-distances were made in 1896. The total number of stars observed is 3,454. The observations for the Ten-year Catalogue, which will contain about 7,000 stars, including 4,000 circumpolars, are now completed. The preparation of the catalogue is in progress ; the mean R.A. and N.P.D. for the years 1887 to 1895 have been entered on separate sheets for each star, and the precessions and secular variations computed in duplicate.

For the next Ten-year Catalogue it is proposed to observe all stars of the ninth magnitude and brighter within 26° of the Pole to serve as fundamental points of reference for the plates of the Greenwich Zone of the Astrographic Chart and Catalogue, Declination 64° – 90°. A working catalogue of these stars for the epoch 1900 is being prepared and is about half finished.

The Moon was observed 121 times with the transit-circle ; the mean error in R.A. of Hansen's Lunar Tables with Newcomb's corrections as deduced from these observations is $-0^{s}\cdot088$. The errors for the years 1883-96 are as follows :—

	s		s		s
1883	+0·031	1888	+0·090	1893	+0·034
1884	+0·018	1889	+0·010	1894	−0·016
1885	+0·024	1890	+0·020	1895	−0·066
1886	+0·029	1891	+0·079	1896	−0·088
1887	+0·059	1892	+0·083		

The progressive change of the error since 1891 is noticeable.

The number of observations of zenith distance of stars by reflexion and directly was 520. The apparent correction to the nadir observations deduced from these which has been consistently

negative throughout the year is −0″·43. For the years 1890 to 1895 the corrections are +0″·08, +0″·07, −0″·25, −0″·34, −0″·27 and −0″·26. The increase of this discordance suggested an examination of the screws of the microscope micrometers and of the telescope micrometer. The former shewed signs of wear, but the reversal of three of the screws has successfully eliminated the effect of wear from the mean of the six microscopes. The errors of the mean readings, as determined in 1886, when the screws were new, in 1893, and in 1896 November are as follows :—

Error of the Mean of the six screws in	Revolution of the Screw							
	9r	0r	1r	2r	3r	4r	5r	6r
	″	″	″	″	″	″	″	″
1886	−0·13	−0·07	+0·03	−0·06	+0·06	0·00	−0·06	+0·10
1893	−0·29	−0·11	−0·11	+0·03	−0·03	0·00	−0·09	−0·11
1896	−0·14	−0·02	−0·02	−0·02	+0·02	+0·10	−0·04	−0·19

The telescope micrometer which was new in 1891 shows considerable wear, though the observations for determining it are not yet completed. It has not yet been ascertained whether the wear of this screw is a sufficient explanation of the change in the apparent correction to the nadir deduced from the reflexion observations.

The observations of zenith distance of pairs of stars at nearly the same N.P.D., the one directly and the other by reflexion, alternately on alternate nights have been continued, giving ninety-seven determinations of the R−D discordance. The similar observations made in 1895 did not show any marked difference from the R−D discordance determined in the usual way.

During January the series of observations with the personal equation machine begun in 1895 was continued on six days. The observations of 1895 and 1896 have all been reduced, giving the personality of six observers for transits of the limbs of the Sun or Moon and of stars.

The Moon has been observed with the altazimuth in the first and last quarters as in previous years, fifty-eight observations being made in the year.

The new altazimuth pavilion and dome were completed early in January, with the exception of a wooden observing floor and móveable roofs over the collimators, which were not finished till August.

On the completion of the observing floor the instrument, whose erection was finished in May, was examined, and serious discordances were found in the readings of the circles under the different microscopes, depending on the direction in which the instrument was last turned. Experiments have been made under Mr. Simms' direction, which show a flexure in the axis; and means are being arranged, in conjunction with him, for stiffening the axis.

Three comets were observed during the year with the Sheepshanks' equatorial—Comet (*a*) 1896 (Perrine-Lamp) on 10 nights, Comet (*b*) 1896 (Swift) on 20 nights, and Comet (*f*) 1896 (Perrine) on 4 nights.

Twenty-six occultations of stars by the Moon were observed during the year. The occultation of *Jupiter* and his satellites on June 14 was observed by five observers; 32 phenomena of *Jupiter's* satellites were also observed.

With the 28-inch refractor 220 double stars have been observed on 91 nights, each star being observed on the average on 2 nights. Of these stars 45 were less than 0″·5 apart, 68 between 0″·5 and 1″·0, and 54 between 1″·0 and 2″·0. The following lists contain some of the more interesting stars measured, in the first the components of the double being of nearly the same, and in the second of widely different magnitudes.

	Distance.	Magnitudes.			Distance.	Magnitudes.	
	″				″		
κ Pegasi	0·10	4·3	5·0	γ^2 Andromedæ	0·20	3	5
β 524	0·22	5·5	6·5	99 Herculis	0·60	6	11
β 800	0·21	6	6	τ Cygni	0·60	4	10
Σ 1728	0·15	6	6	β 1251	1·2	6	11·5
Σ 1639	0·15	6	6·5	ζ Herculis	0·54	3	6
				ζ Aquilæ	5·6	3	15

The satellite of *Neptune* has been measured on 4 nights, the diameter of *Neptune* on 2 nights, and the diameter of *Mars* on 6 nights with the bifilar micrometer. A series of comparative measures of *Jupiter's* diameter with the bifilar and double image micrometer was communicated to the Society and published in the *Monthly Notices*, 1896 May. A water-tank has been placed on the flat of the lobby of the dome to supply the driving-clock of the equatorial, and has made a material improvement in the steadiness with which the telescope is driven.

Sir Henry Thompson's valuable gift to the Observatory of an equatorial with a photographic refractor of 26-inches aperture mounted on one end and a Cassegrain reflector of 30 inches on the other end of the declination axis is being erected in the New Physical Observatory under the 30-foot dome. The equatorial and the refractor were constructed by Sir Howard Grubb; the figuring of the mirrors and supervision of the construction of the reflector were kindly undertaken by Dr. Common. The Merz refractor ($12\frac{3}{4}$-inch) is mounted as a guiding telescope for the refractor, and the Thompson photoheliograph is also attached to the 26-inch refractor. A new spectroscope adapted for photography has been made by Mr. Simms for use with the reflector or refractor.

With the astrographic equatorial 365 plates with 722 exposures were taken on 111 nights. Of these 101 have been

rejected—viz., 15 as not coming up to the standard in showing faint stars, 13 from the *réseau* being imperfectly printed, 15 because of wrong setting, 16 owing to faults in the plate or in development, 10 owing to fogging of the plates, 11 because the exposures were interrupted by cloud, and 21 from miscellaneous defects. Of the 264 successful plates, 96 are for the chart, 131 for the catalogue, 7 are of standard areas, and 30 were taken for the adjustments of the instrument.

As the work advanced towards the pole the change of orientation resulting from the errors of collimation and inclination of the declination axis of the equatorial introduced difficulties which made it necessary to correct these errors mechanically. From measurements of trails on plates taken near the pole and equator and in reversed positions of the telescope it was found that the errors of collimation and inclination of declination axis were each $-6'$. These were eventually reduced on December 15 each to $+0'{\cdot}6$—one-tenth of the original amount—by the insertion of thin plates of copper between the telescope and its cradle, and in the cube of the cross-head.

The following table shows the progress of the photo-mapping of the heavens to the end of 1896 :—

	Catalogue.	Chart.
Number of successful fields on 1895 Dec. 31	685	479
Number „ „ taken in 1896	112	94
Number previously passed rejected during 1896 ...	28	89
Number of successful fields 1896 Dec. 31	769	484
Total number still required	380	665

The eighty-nine chart plates which are rejected are unsuitable for reproduction, though in most cases good plates otherwise. Since the last report, positives on glass have been taken of 321 chart plates, which, added to the thirty-seven reported last year, gives a total of 358. The rest of the chart plates are being copied.

During the year the rectilinear co-ordinates and diameters of the 6^m and 3^m images have been measured on 211 plates. Of these, 125 plates were measured for the first time, and eighty-six were remeasures, the plates being reversed in the holder of the micrometer. The complete remeasurement of the plates in the reversed position which has been undertaken with a view to securing increased accuracy in the results has been found to be of great advantage in the detection of errors, and for the elimination to some extent of personality in measurement. The progress made with the measurement of the photographs to 1896 December 31, is as follows: The 6^m and 3^m images on all the plates or halves of plates between 65° and 68° N. Decl. have been measured once. From 65° to 66° they have been measured twice. The southern halves of the plates in zone 65° have been measured once for two-thirds of the zone, and twice for one-third.

Altogether 252 plates have been measured once and eighty-six twice.

During the year 126 plate constants have been determined. To the end of 1896, plate constants have been computed for the whole of zone 66°, and for large portions of zones 65° and 67°; altogether for 198 plates.

The division errors of the *réseau* Gautier, No. 35, have been determined. Five plates of the same field have been measured direct and reversed by one observer, and a plate has also been completely measured direct and reversed by five measurers, giving ten sets of results for the determination of personality of the observers in the two positions of a plate, and for the determination of the probable error of the measures. The probable error of the mean of the four measures of a star on a plate (6^m and 3^m images, each measured direct and reversed) is thus found to be $\pm 0''.13$, and this is reduced to $\pm 0''.11$ by applying the correction for personality.

Photographs of the Sun were obtained with the Dallmeyer photoheliograph of four inches aperture on 231 days. Of these, 496 have been selected for preservation, including sixteen with a double image of the Sun, taken to determine the position of the wires with reference to the parallel of declination. Photographs have also been received from India up to 1896 December 2, and from Mauritius up to 1896 November 2, leaving only two days—1896 February 14 and August 10—for which no photograph is available for measurement in the year ending with the date of the last Mauritius negative received.

The Greenwich photographs have been measured in duplicate up to the end of 1896, and the Indian and Mauritius photographs so far as they have been received. The areas and heliographic positions of the spots and faculæ have been computed throughout. The complete results for 1894 have been printed, and the results for 1895 have been passed for press up to April 4. Hitherto, little relief has been felt from the decline in the solar activity, which began to be noticeable in 1895, and which has been more evident in 1896; since the measures and reductions of the two very heavy years of maximum, 1893 and 1894, have only recently been completely disposed of. The mean daily spotted area of the Sun for 1895, expressed as usual in millionths of the visible hemisphere, is approximately 974, and for 1896, so far as the record is as yet complete, 524; as compared with 1464 for 1893, and 1282 for 1894, and with 1155 for 1883, the maximum year of the last cycle. On the three days 1896 April 15, 16, and 17, the Sun was free from spots; the first occasion upon which this has been the case since 1891 March 28.

Transit observations at contiguous stations in the front court, to determine the difference of longitude between them, have been continued on five nights with the instruments used in Paris-Greenwich longitude determinations. The observations, as well as those of 1895, are partly reduced.

The volume of *Greenwich Observations* for 1894 is printed with the exception of the Introduction, of which proofs have been received and returned to the printers. The transits and a large part of the zenith distances are printed for 1895. It is proposed from the beginning of 1897 to limit the printing of the details of the meridian observations to the observations of the Sun, Moon, planets, and fundamental stars (stars for clock-error, azimuth, and zenith point), and only to give results (mean R.A. and N.P.D. for each observation) for other stars.

The north wing of the new Physical Observatory is ready for occupation. The Lassell dome, which was dismounted by Messrs. Cooke last year, has been re-erected on the central octagon of the new building. Provision has been made in the Navy Estimates for commencing the building of the east and west wings, and thus completing the Physical Observatory.

Reference was made in the last report to the retirement of Mr. Criswick on 1896 January 31. Mr. Hollis was promoted to fill the vacancy thus occasioned in the staff of first-class assistants. In accordance with a rearrangement of the staff, which came into force in April, Mr. P. H. Cowell, M.A., Fellow of Trinity College, Cambridge, was appointed as the additional chief assistant to supervise the work in conjunction with Mr. Dyson, and Messrs. Davidson, Edney, Rendell, and Bowyer were added to the permanent staff as established computers.

It may be mentioned that the Astronomer Royal went to Japan, and Mr. Maunder and Mr. Crommelin to Norway, to observe the total eclipse of the Sun on August 9. No observations during totality were obtained at either station owing to cloud.

Royal Observatory, Edinburgh.

The mounting of the Grubb 24-inch reflector from Calton Hill in the west dome was begun in January. The driving clock has been fitted with an electric control by Messrs. Ritchie & Son, of Edinburgh. This clock is also arranged to drive the large four-barrel Cooke chronograph, which with the Fuess chronograph is mounted in the room under the west dome.

The clock-chamber in the base of the great pier of the east dome was found to be much affected by the moisture expelled from the cement during the process of hardening, but inconvenience from this source has been obviated by exposing within the chamber a large surface of calcium chloride in copper pans.

The time-service has been maintained under the care of Mr. Heath as in former years. This service comprises the working of the time-ball on the Nelson Monument, the firing of the time-gun at Edinburgh Castle and at Dundee, as well as the controlling of various clocks in the City of Edinburgh.

The regular meteorological record was begun at Blackford

Hill on 1896 January 1. Two rain-gauges are used, one on the grass, and the other on the roof of the main building; the thermometers (including dry and wet bulb, maximum and minimum) are mounted in a louvre screen near the grass rain-gauge. The cistern of the standard barometer, which is mounted in the barograph room, is 441 feet above sea-level. The King recording barograph, by Casella, has been in constant action since the beginning of the year. It was not until April that the recording anemometer was mounted on a tall iron lattice-pillar, erected above the porch of the detached observing house containing the 6-inch refractor. The continuous record of the velocity and direction of the wind began on July 17. Among the exceptionally high velocities recorded may be mentioned that of 68 miles per hour which occurred between 9 A.M. and noon on October 8. Abstracts of the meteorological observations are supplied each month to the Scottish Meteorological Society, and are inserted in the returns of the Registrar-General for Scotland. The rock thermometers at Calton Hill continue as formerly to be read once a week by one of the staff of the Royal Observatory.

On 1896 April 7 the new observatory at Blackford Hill was formally opened by Lord Balfour of Burleigh, Secretary for Scotland. The Earl of Crawford and Balcarres, to whose munificence the observatory is indebted for the fine collection of instruments from Dunecht as well as the exceedingly valuable Crawford Library, was present, and gave an interesting account of the founding of the new observatory.

Before the official opening, the efforts of the staff were directed towards mounting the instruments and putting them generally in order. The Dunecht meridian circle of 8·6 inches aperture, by Troughton & Simms, was mounted on its piers in the transit-house. Owing, however, to some defects in the roof-shutters, the instrument was afterwards removed from the Ys, and was not finally remounted until November, when the imperfections of the shutters had been satisfactorily remedied. The object-glass has been retouched, and the illuminations have been improved by the makers. Throughout the year the time-observations have been made with the 4-inch Cooke reversing transit.

In March the Council of the Royal Society of Edinburgh generously placed at Professor Copeland's disposal a grant for an expedition to Vadsö, in Finmark, to observe the total eclipse of the Sun on August 9, and preparations for it were begun in April immediately after the formal opening of the observatory. The equipment, which was wholly photographic, consisted of—

(1) A 40-foot telescope, with Dallmeyer lens of 4 inches aperture.
(2) A 6-inch telescope, with object-glass prism and camera, mounted equatorially, with driving clock.
(3) A camera with Dallmeyer lens of 4 inches aperture and

33 inches focal length, on a 4-inch Cooke equatorial stand, with driving clock.

(4) A camera with quartz lens of 1·8 inch aperture and Iceland spar prism, on the same stand as the 6-inch.

(5) A whole-plate camera, with Dallmeyer lens of 1½ inch aperture and 10½ inches focal length, also on the 6-inch stand.

The 40-foot tube was mounted on wooden trestles so as to point exactly to the place of the Sun at the middle of totality, while the Sun's motion was allowed for by driving the plate-carrier at exactly the required speed, on the plan so successfully adopted by Professor Schaeberle in 1893. The plates for this telescope measured 18 inches square. The driving clock was kindly lent by Lord McLaren.

All these instruments were mounted and carefully tested at Blackford Hill before being sent off, and the members of the expedition—viz. the Astronomer Royal for Scotland, Mr. Ramsay, and Engineer McPherson, along with Mr. Theodore B. Copeland, who kindly volunteered his services, sailed from Newcastle on July 18. Vadsö was reached on July 28, and on the same day several of the instruments were conveyed to the eclipse station on the Fossefjeld, 2½ kilometres to the north of the town. By the day of the eclipse all the instruments were mounted in perfect working order, and only favourable weather was needed to ensure the success of the expedition. Unfortunately the sky was completely clouded at the time of totality; but some seconds afterwards the clouds partially cleared, and Mr. Ramsay succeeded in obtaining five plates of the crescent Sun with the 40-foot telescope. As was to be expected, however, no trace of corona appears on any of them; they distinctly show the irregularities on the Moon's limb. Mr. Theodore Copeland also obtained several plates of the crescent Sun with the Dallmeyer 4-inch camera. The expedition was much indebted to the Amtmand of Finmark for his aid in selecting the station, and to the Norwegian naval authorities, who placed a guard of sailors at their disposal.

The expedition party left Vadsö on August 13, and on arriving that day at Vardö had the satisfaction of greeting Dr. Nansen on his arrival in the *Windward*.

The Bifilar pendulum, presented by M. Antoine d'Abbadie, in 1894, was removed from Calton Hill in October 1895, and in the beginning of August 1896, was remounted at Blackford Hill, by Mr. Heath, who has charge of the instrument. A photographic apparatus, also presented by M. d'Abbadie, for continuously recording the position of the mirror, was at the same time placed in position, and has on the whole worked satisfactorily, although some difficulty was at first experienced in maintaining the uniform motion of the sensitive paper. Occasional interruptions of the record have occurred from this cause, but it is hoped that the

difficulty has now been overcome. The record shows several well marked deflections which have in part been identified with distant earthquakes; they are described in "Nature" of 1895 July 4 and 1896 November 5.

On all favourable occasions the 15-inch refractor has been employed in the observation of Comets and Minor Planets by Dr. Halm, who also redetermined the screw value of the micrometer. The following observations were secured:—

Comet 1895 IV.	... ...	4 observations
„ 1896 I. ...	... ...	25 „
„ 1896 III.	... ...	10 „
„ 1896 IV.	... ...	1 „
„ 1896 (Perrine, Nov. 2)	... ...	15 „
„ 1896 (Perrine, Dec. 8) ...	... ...	4 „
19 Minor Planets	... ...	70 „

These observations have all been reduced and the results communicated to the Royal Astronomical Society, or published in the *Astronomische Nachrichten*. Just before the end of the year the large Cooke spectroscope was attached to the 15-inch refractor, and a series of spectroscopic observations of Mars was begun. Dr. Halm has also made further observations for the latitude with the reversing transit in the prime vertical.

During the total eclipse of the moon on February 28, twenty photographs were secured by Mr. Ramsay with the 12-inch Browning reflector, while visual observations of disappearances and reappearances of craters were made by the other members of the staff. The occultation of the Pleiades on March 19 was also observed.

On November 13 four plates were exposed in the $1\frac{1}{4}$-inch camera mounted on the 4-inch equatorial stand, with the view of photographing the Leonid meteor tracks, but although several bright meteors were observed in the region to which the camera was directed, no trace of them appears on the plates.

During the year two circulars were issued containing elements and ephemerides of Comet *Perrine* (November 2) by Dr. Halm, and by Dr. Knopf, of Jena.

The new reduction of the right ascensions of the Henderson observations, in the hands of Mr. Heath and Dr. Halm, now appears to have removed the greater part of the systematic errors, which, in consequence of the imperfect knowledge of their physical causes and the provisional character of the earlier reductions, had seriously affected the positions of the catalogue. The accuracy of the computations made by the late Mr. Wallace has been proved by a thorough examination of the reductions to the mean of wires for the years 1834–36 and a comparison with the original note-books. On turning to the instrumental errors, however, it soon became apparent that the greatest care would

have to be given to this part of the new reductions. It is true that Henderson himself had grave doubts as to the stability of the instrument and suspected its liability to disturbance by change of temperature—indeed, he succeeded in bringing out a remarkable correspondence between the observed level readings and the indications of a thermometer slightly below the surface of the rock within the grounds of the Observatory. To his successor, Professor C. Piazzi Smyth, is due the great merit of extending these investigations to the azimuth, and of disclosing by the clearest reasoning combined with experiment the probable source of these variations. It is one of the most satisfactory results of the new reductions to have proved the correctness of Professor Smyth's conclusions by a totally different course of investigation.

But, notwithstanding the pains bestowed by Professor Smyth in applying these improved corrections to the observations, there still remained certain discrepancies incapable of satisfactory explanation, although their existence became known to the observers through the establishment of meridian marks to the north and south of the Observatory. At first sight it seemed probable to us that the clock might be taxed with these discordances, which were marked by a considerable difference in the clock errors day and night, but it soon became evident that this difference, amounting to more than one-tenth of a second, changed sign on the reversal of the instrument. The discordance arises almost suddenly at the beginning of the night, and then remains constant till the reappearance of daylight; this places it almost beyond doubt that these well-marked changes of the collimation are connected with the mode of illumination, the matter being, however, further complicated by the fact brought out by the pole stars, that the effect varies somewhat with the zenith distance. The numerical value of this "illumination correction" is remarkably constant, and reduces the accidental errors of the transits so considerably that we may now expect very satisfactory results from these valuable observations. The years 1834 and 1835 have been completely reduced; the resulting mean right ascensions show a remarkable freedom from systematic discordances, the agreement between the upper and lower culminations especially having been much improved. The instrumental errors for 1841–45 have been computed and tabulated, the data for these years being more complete than for the earlier period. The same work for the intervening years, 1837–40, is now being carried out. The clock stars for 1841 have been definitely reduced and the clock corrections derived.

Royal Observatory, Cape of Good Hope

Her Majesty's Astronomer was absent on leave from April 1 to December 1. During his visit to Europe he attended the meeting of the Permanent Committee of the Astrographic Con-

gress, held at Paris in May last. He also represented the observatories of the southern hemisphere at the Conference of Directors of National Ephemerides, held at Paris in the same month, on the question of adopting a uniform catalogue of fundamental stars and uniform constants in the National Ephemerides. As a delegate of the Cape Colony, he attended the International Congress, summoned by the Royal Society, to consider the question of the creation of a general subject catalogue of scientific literature.

Whilst in London, he reported officially to the Lords Commissioners of the Admiralty on the long-standing needs of the Cape Observatory in regard to an increase of staff and the supply of a meridian instrument (with a detached observatory) suitable for refined fundamental determinations. The Lords Commissioners of the Admiralty and of H.M. Treasury have favourably considered these proposals, and provision will be made for giving effect to them in the Navy Estimates for the financial year 1897-98.

Mr. Robert T. A. Innes has been temporarily appointed secretary and accountant ; no other changes have taken place in the staff.

The policy of pressing forward arrears of reduction has been maintained, and it has become possible to revert to a programme of activity in stellar meridian observation. Other departments are still cramped from want of staff. The annual results of meridian observations of stars for the years 1890 and 1891 have been placed in the hands of astronomers.

The annual results for 1892, 1893, 1894, and 1895, have been passed through press.

Volume ii. of *A Determination of the Solar Parallax and Mass of the Moon from Observations of Iris, Victoria, and Sappho, in the years* 1888 *and* 1889 is ready for distribution. This volume contains a description of the instruments and methods of observation, the details of the heliometer observations, Dr. Auwers' discussion of the meridian observations of the comparison stars, and convenient refraction tables for heliometer observations by Professor Harold Jacoby.

Volume i. of the same work has been completely passed through press, except the introduction and index, which are still in the printer's hands. This volume contains :—

Part 1. Discussion of the Heliometer triangulation of the *Victoria* comparison stars.

Part 2. Discussion of the heliometer observations of *Victoria*.

Part 3. Discussion of the heliometer observations of *Sappho*.

Part 4. Discussion of the heliometer observations of *Iris*.

Part 5. Discussion of the meridian observations of the same planets.

Part 6. A general discussion and combination of the results.

Of this work, part 4 is by Dr. Elkin ; part 5 by Dr. Auwers. An advance proof of part 6 was placed in the hands of members of the International Conference, which assembled at Paris on May 18 last.

The definitive values of the astronomical constants determined by the heliometer observations, and those recommended by the Conference for use in the National Ephemerides, are as follows :—

	From the Heliometer Observations.	Recommended by the Conference.
Mean Solar Parallax	8″·802 ± 0″·005	8″·80
Mass of the Moon	1 ÷ 81·702 ± 0·094	—
The constant of Nutation ...	9·207 ± 0·003 (1)	9·21
The constant of Aberration ...	20·467 ± 0·012 (2)	20·47

(1) Derived from the constant of precession and mass of the Moon.
(2) Derived from the solar parallax and Newcomb-Michelsen velocity of light.

Volume i. of the *Cape Photographic Durchmusterung*, containing the places of 152,000 stars, derived by Professor J. C. Kapteyn, from the Cape photographs, between the limits of declination − 19° and − 37° (both inclusive), has passed through press and is ready for distribution.

Volume ii. of the same work, containing the places of 158,000 stars, between the limits of declination − 38° and − 52° (both inclusive), is in course of printing.

An account of the Geodetic Survey of South Africa, executed by Colonel Morris, R.E., C.M.G., under the direction of H.M. Astronomer, with a re-reduction of Sir Thomas Maclear's triangulation, has been presented to the Cape Parliament, and distributed to astronomers and others interested in geodesy.

The manuscript of the Cape Ten-Year Catalogue of 3,007 stars for the equinox 1890, based on meridian observations from 1885 August 24 to the end of 1895, is practically completed, and, with the exception of the introduction, will be in the hands of the printer before this report is published.

The meridian observations (stellar and planetary) 1861–65, made under the direction of Sir Thomas Maclear, but which have remained unreduced to the present time, are completely reduced, and the manuscript (excepting the introduction) is ready for press.

The reduction of the remainder of Maclear's observations is in progress :—

The right ascensions are reduced to observed R.A. till 1866 December 31.

The clock errors are computed to 1867 May 12.

The N.P.D.'s are reduced to mean N.P.D. 1866 December 31.

The N.P.D.'s are reduced to observed N.P.D. 1868 June 1.

Duplicate independent computations of the star corrections for all stars (except *Nautical Almanac* and Polar stars) are computed for all the observations 1866–69, and one copy for those of 1870.

3,018 stars, to be employed as standard stars for the astrographic catalogue plates (ten stars per plate), have been selected for the zone − 40° to − 43°, and the meridian work has been chiefly devoted to their observation.

Meridian observations have also been made of a list of 108 stars forwarded by Professor J. C. Kapteyn for special observation.

During 1896 the following transit circle observations have been obtained.

Meridian Transits	9,000
Determinations of Declination	8,677
,, ,, Collimation	98
,, ,, Level	327
,, ,, Azimuth	212
,, ,, Runs	315
,, ,, Nadir	311
,, ,, Flexure	52
Observations of the Meridian Mark Z.D.	45
,, ,, ,, ,, Az.	138

Of these observations :—

Apparent R.A. is computed to December 27.
,, ,, examined to December 20.
,, N.P.D. computed to December 26.
,, ,, examined to December 19.
Mean R.A. and N.P.D. examined to September 20.
Ledger prepared to August 20.
Star corrections computed to December 18.
,, ,, examined to December 6.

The following occultations of stars by the Moon have been observed :—

Predicted by the *N. A.* Office for the Cape.	Disappearance of Stars at the Bright Limb	2
	Disappearance of Stars at the Dark Limb	16
	Reappearance of Stars at the Bright Limb	1
	Reappearance of Stars at the Dark Limb	13
Not so predicted.	Disappearance of miscellaneous Stars, Dark Limb	44
	Reappearance of miscellaneous Stars, Dark Limb	1
	Daylight occultation of α Leonis D and R	2 by 1 observer
	Daylight occultation of Antares D and R	2 by 2 observers
	Total phenomena observed ...	81

Of the occultations predicted by the Nautical Almanac Office four were observed by three observers, nine by two observers, nineteen by one observer. The occultations of miscellaneous stars were observed chiefly by one observer—Mr. Innes.

The same observer has devoted himself with great success to a search for southern double stars, and the examination of stars which, in course of preparation of the Cape Photographic Durchmusterung, have been suspected by Professor Kapteyn of variability.

With the 7-inch equatorial Mr. Innes has found during the year no less than 104 new double stars, of which forty-five are of distance 0″·6 to 1″, thirty-one of 1″ to 2″, and seven have very faint companions exceeding 5″ distance, the remainder being within the limits 2″ to 5″. The duplicity of three other stars has been detected by the transit circle observers. A list of these stars for communication to the society is attached.

Over 300 stars, to which attention has been drawn by Professor Kapteyn, have been regularly observed for variability, mostly with negative results; but many of these, in addition to the following variables already found, are still under observation.

		h	1875. h m s	° ′		
1	Z.C.	8·4821	8 59 35	−24 35·5	Innes	Mag.*
2	O.A.	10288	12 54 7	−19 46·7	,,	,, 9·0 to 9·9
3	Z.C.	13h·2483	13 41 2	−36 14·2	,,	,, 8·1 ,, 10·5
4	Gould	19229	14 4 22	−28 17·6	,,	,, 9·0 ,, under 12·5
5	Z.C.	15h·3719	15 52 56	−29 33·9	,,	,, 9·0 ,, 10·5
6	Z.C.	15·4006	15 57 8	−23 45·2	,,	,, 8·0 ,, 10
7	Z.C.	16·2278	16 32 36	−32 7·9	,,	,, 8·2 ,, 9·4 deep red
8	O.A.	16813	21 19 19	−30 23·4	Finlay	,, 8·0 ,, under 12·5

The discovery of Nos. 3, 6, 7, and 8 has been announced, *Ast. Nach.* 3,389.
No. 4 is also in Thome's list of suspected variables.
From Thome's list of suspected variables there was also found

9	Th.	−33°·185	0 27 1	−33°·34	Innes	Mag. 10·2 to under 12·5

With the Astrographic telescope the following work has been accomplished :—

	No. of Plates exposed.	Exposures. No.	Exposures. Duration.
Catalogue plates	55	165	6m 3m 20s
Chart plates (even degrees)	237	237	60m
Chart plates (uneven degrees, triple exposure)	7	17	30m each image
Standard areas	37	111	6m 3m 20s
Comparison of standard areas with south pole area	8	54	6m 3m 20s
Plates for light curve of R Velorum	23	94	6m
Stars suspected of variability in Kapteyn's discussion of the Cape Phot. Durchmusterung	133	379	6m
The cluster in Toucan	9	9	5m to 2h
Trails, &c.	10	22	
	519	1088	

* Proved variable 1896 April 19, May 20, 10m·2, invisible May 26, but was published variable in Harvard Circular, No. 7, June 5.

The photographs of the cluster in *Toucan* have been made at the request of Dr. Alexis Hansky, of the Pulkowa Observatory.

The catalogue plates are now all taken, but investigations under the measuring machine have led to some repetitions—a few of these on account of faulty images, but generally on account of paucity of stars.

No provision has yet been made for the regular measurement of the catalogue plates, but 26 catalogue plates (5,743 stars) have been measured in course of the year as opportunity offered.

The number of stars per plate has varied from 53 on the plate $-42°$ 4^h 40^m, to 780 on the plate $-42°$ 8^h 10^m.

The coordinates and diameters of the star-discs on every plate have been measured independently by two observers.

A more rapid and yet sufficiently accurate method of measurement is now under consideration and arrangement. Provision will be made for carrying on the work of measuring the catalogue plates on a much greater scale after 1897 April.

Of the 237 chart plates exposed, 169 have been passed as satisfactory; this leaves 84 of the even degree, single image plates yet to be done. Of the seven uneven degree triple exposure plates taken, two were stopped by cloud after one image had been impressed.

The triple exposed plates are extremely satisfactory, as they render the existence or otherwise of a star a matter of perfect certainty. The guiding telescope has been furnished with three spider webs in the common focus of the object-glass and eyepiece. These webs form a small equilateral triangle (sides about 8″), and the guiding star is placed successively in the three angles of this triangle.

The 36-foot dome of the McClean Observatory, by T. Cooke & Sons, of York, has been erected by one of the foremen of the firm (Mr. Selby) sent out for the purpose. The dome is a thoroughly satisfactory piece of work, excellent in design as well as workmanship, and easy and convenient in use.

The observatory building itself cannot be quite completed till the heavy castings of the telescope stand have been placed *in situ*.

Unexpected delay has occurred in the completion of the telescope, but when H.M. Astronomer visited Dublin in November last Sir Howard Grubb promised that the instrument would be completed in four months from the time when the base castings (expected immediately) arrived. The prisms and object-glasses for the star spectroscope have been received from Mr. Brashear, the working drawings have been completed, and the construction of the instrument has been commenced by the Cambridge Scientific Instrument Company. The rising floor with its hydraulic machinery reached the Cape in October, and its erection was commenced immediately on Dr. Gill's arrival from England on December 1; considerable progress has been made in this work.

It is expected that before the end of 1897 the McClean telescope and observatory will be in full working order.

The time-signal service has been regularly maintained. The meteorological observations made at the observatory in 1895 have been communicated for publication to the Cape Meteorological Commission.

Cambridge Observatory.

The *Catalogue of Zone Stars* is now printed, and only requires the Introduction and Appendix to complete the volume.

It gives the places of 14,441 stars, with a few additional which will appear in the Appendix. Each of these has been observed, on an average, about four times.

A discussion of all the stars observed seven times and upwards, and a few in the first hour of right ascension which had been observed five or six times, taken indiscriminately, two only being omitted which gave clear indication of proper motion—in all, 945 places deduced from 7,461 observations—gives for the probable error of one observation

$$\text{in R.A. } \pm 0^{s}\cdot 06608$$
$$\text{in Decl. } \pm 0''\cdot 5079.$$

Guided chiefly by the letters affixed in the *Durchmusterung*, about 9,000 places in this catalogue have been compared with the older catalogues. This comparison has brought to light not a few interesting and decided cases of proper motion. A list of these cases has been drawn up for re-observation, and a good number have been already observed.

The manuscript for an enlarged catalogue, which is to contain the result from each individual observation of each star, has been carefully revised, and the first ten hours are copied for the press.

The Newall Telescope, Cambridge Observatory.

The Newall Telescope has been used for observations on 112 nights in the course of the year 1896, this number being the smallest in any year since the instrument was set up at Cambridge. The "seeing" has been unusually poor, especially in the latter half of the year.

Almost the whole year's work has been devoted to spectroscopic work with the Bruce Spectroscope. A description of this instrument has been published in the *Monthly Notices*, vol. lvi. p. 98. The only alteration in the arrangement there described has been the substitution of a new correcting lens made of denser flint, by Messrs. Cooke & Sons. This lens gives very satisfactory results, with increased density and extension in the photographic spectra on the ultra-violet side of Hγ.

The investigations undertaken in the early part of the year were chiefly determinations of velocity in the line of sight in the case of various bright stars. Iron, helium, and hydrogen have been used for comparison spectra, with a view of comparing the results obtained with the classical work of Dr. Vogel, in which hydrogen was used. The velocities deduced from the discussion of the photographs showed signs of a more or less systematic difference from the Potsdam results. It is well known that the greatest difficulty in determination of velocity in the line of sight is the arrangement of the comparison spectrum. Accordingly the greatest care was bestowed at the outset on the adjustment of the apparatus provided in the Bruce Spectroscope, in order that the position of the comparison spectrum on the plate should be irrevocably set by the instrument, and should not be in any way at the arbitrary disposal of the observer; but it appears that latterly a displacement has occurred to which the discrepancies from the Potsdam results must in part be referred, and the exact cause is still to be explained.

The troublesome search for a comparison spectrum which shall be above suspicion has involved a great deal of what may be described as underground work, and has in great measure thrown back the astronomical investigations. But for the guidance of other workers, who may wish for information relating to the spectra and not relating to the velocities of the stars, it may be of interest to state that the spectra of the following objects have been specially studied :—

α Aquilæ	γ Cygni	β Orionis
α Aurigæ	α Geminorum	γ Orionis
α Boötis	β Geminorum	α Pegasi
β Cassiopeiæ	α Leonis	α Persei
γ Cassiopeiæ	α Lyræ	Jupiter
α Cygni	α Orionis	Venus

Dunsink Observatory.

For two months in the early part of the year observations with the meridian circle were discontinued in order to complete the work of preparing a catalogue for the press. Early in March this was accomplished, and in July the catalogue, forming Part vii. of *The Astronomical Observations and Researches made at Dunsink*, was published and distributed. This contains the separate observations of 717 stars, and their mean places for the epoch 1890. The probable error of these places as deduced from the separate results for all those stars which were observed more than three times is for a single observation—

in R.A. $\pm 0^s.037$

and

in Decl. $\pm 0''.505$.

In bringing this work to a close, it was intended to discontinue meridian observations for the present, in order to carry on the photographic work with the "Roberts" equatorial more vigorously.

Several things have, however, conspired to alter this intention, and during the year the main observing strength has still been devoted to observations with the meridian circle. The details of the reduction of measurements on photographic plates for the detection of stellar parallax had not yet been completely worked out, and some points in the management of the telescope remained to be experimentally tested. It seemed well, therefore, to proceed with the observations of the Zodiacal stars required by Dr. Downing for use in the *Nautical Almanac*, and of some other stars, including some of those in Part vii. of which further observations seemed desirable.

During the year there have been in all 6,321 observations made with the meridian circle. This number includes 169 observations of the error of collimation of the instrument, 176 of the level error, 148 of the nadir point (by reflexion), and 29 of the error of runs of the microscopes. For determining the error of azimuth 101 transits of polar stars have been observed; for determining the error of the Dent sidereal clock 531 transits of standard stars have been recorded; and for the equator point of the circle 443 observations of the zenith distance of these stars have been made. The observations of stars on the working list amount in R.A. to 2,355, and in Decl. to 2,369, which have all been reduced to apparent place up to the date October 6.

With the "Roberts" equatorial 77 photographs have been taken, representing 109 exposures of various lengths. The objects photographed include the great cluster in *Perseus* (G. C. 512 and 521), *Præsepe* and M 13 (*Herculis*); the nebula H. IV. 37, the annular nebula in *Lyra*, and the great nebulæ in *Andromeda* and *Orion*, and a number of stars, including η *Cassiopeiæ*, η *Ursæ Majoris*, ϵ *Lyræ*, and others.

Photographs were also taken of Comet *b* 1896 on the nights of April 29 and 30 and May 2 and 8.

Some time has been spent in experimenting on a method of allowing for the inequality which the motion of a star undergoes in consequence of refraction, and very satisfactory results have been attained by employing a mercury compensation pendulum, the rate of which can be accurately controlled and adjusted to the rate of movement of a star by altering the weights on the shelf of the pendulum from time to time during an exposure, according to the formula given in a paper published in the *Monthly Notices* for December.

The "South" equatorial was employed for observing the transits of the "garnet" spot on *Jupiter* on thirteen nights in February and March. These observations were employed for determining the period of rotation of this marking, and the result was published in the *Proceedings of the Royal Dublin Society*, vol. viii. part v. No. 49.

Observations of the *Leonids* were made on the mornings of November 14 and 15 (civil time) and an attempt, which was unfortunately unsuccessful, was made to obtain photographs of the trails of some of them. The results of these observations are published in the *Monthly Notices* for December.

The preparations for observing the eclipse of August 8 and the expedition to Vadsö, in which the director took part, necessarily occupied time, and interfered with more productive observations for some weeks in August.

The time service to Dublin has been maintained as in former years; and on the first Saturday of each month the Observatory has been open to visitors, and the 12-inch "South" refractor placed at their disposal.

Durham Observatory.

Regular meteorological observations have been taken and the usual reports issued, but persistent bad weather has made regular astronomical observations almost impossible.

The curators are making arrangements for setting up an Almucantar to take the place of the old transit circle. Experiments have been made to ascertain the effect of wind upon it. It is hoped that the instrument may be set up and in use before the next report.

The library is being rearranged, overhauled, and catalogued.

City Observatory, Calton Hill, Edinburgh.

In accordance with an agreement entered into between the authorities of the Crown and the Corporation of Edinburgh, the buildings and grounds of the old Royal Observatory were formally handed over to the Town Council at the beginning of last year. Since then the work of reconstructing the observatory has been rapidly proceeded with. The main buildings were repaired and painted, and several alterations and improvements made, particularly in connection with the central dome and photographic rooms. The alterations in this dome were rendered necessary for the efficient working of the new 6-inch Cooke visual and photographic equatorial, which, along with a large spectroscope and chronograph, was presented to the observatory early in the year by Mr. W. McEwan, M.P.

The main buildings also contain the mural circle and 6-inch transit instrument, which were kindly left on permanent loan by the Crown authorities, on the recommendation of the Astronomer Royal for Scotland. Both of these instruments are in excellent working condition.

The McEwan barrel chronograph by Messrs. Cooke & Sons,

and a ribbon chronograph, have been fitted up in the transit-room, and have since been constantly employed in observations for time.

For the accommodation of the other instruments belonging to the Corporation, several new buildings had to be erected in the grounds. The first of these is a large octagonal stone house, 38 feet in diameter, with dome, by Sir Howard Grubb, for the accommodation of the large refractor of nearly 22 inches aperture and 30 feet focal length. The dome, which has just been completed, has turned out to be a great success. The covering is of paper, $\frac{3}{8}$ of an inch in thickness, riveted on to angled iron ribs. The revolving apparatus of the dome, which works most efficiently, consists of the usual "live ring," and contains eighteen rollers, each $17\frac{1}{2}$ inches in diameter. Notwithstanding the great weight of the structure, the workmanship is so perfect that a tangential pressure of not more than five pounds is sufficient to move the dome. The second building is a drum dome 18 feet in diameter, containing a reflecting equatorial telescope of 13 inches aperture, the gift of Mr. R. Cox, M.P.; and the third building, which is still in the workmen's hands, is a paper-covered dome, 18 feet in diameter, and which is intended to shelter the equatorial reflecting telescope of 13 inches aperture, kindly presented to the observatory by Lord Crawford and the Astronomer Royal for Scotland. There is also a small transit house with 3-inch transit circle for the use of students. In connection with these various buildings there is being introduced a system of sidereal clocks governed by the standard clock of the observatory; while in connection with the standard mean time clock, and controlled by it, there will soon be in operation several mean time clocks distributed throughout the city.

Glasgow University Observatory.

The work done with the transit circle was preliminary to the observations of the rectangular co-ordinates of the principal pole stars, and of the three stars which are nearest to the pole. After the new micrometer by Troughton & Simms had arrived in February, the screw value was determined, and the progressive errors of the collimation screw were derived. The screw is almost perfect, the range of the corrections not exceeding 0·008 on 40 revolutions.

A series of observations of the division errors of the Ertel circle having shown that they were influenced by systematic errors, it was found that the plane of the end of the axis, and that of the end-thrust, were not at right angles to the axis, thus causing the circle to alter its distance from the microscopes; to obviate this, a knob was then soldered to the end-thrust at its centre. Great care was bestowed on the adjustment of the

microscopes in a plane which passes through the axis of rotation. The telescope was directed towards one of the collimators, the microscopes were read, and the readings were repeated after the circle had been moved 0·02 inch away from the microscopes.

For the determination of the division errors, the same arrangement was adopted that was employed by C. A. F. Peters in his investigation of the errors of the Pulkowa vertical circle by Ertel. There was, however, this difference, that the errors of division of every fifth degree were determined with equal precision, the intervals measured being 90°, 75°, 15°, 70°, 20°, 60°, 30°. For the mean of four microscopes the corrections do not exceed 0″·5.

The spectroscope was mounted on the twenty-inch Breadalbane reflector, but it has not yet been used on celestial objects, because it was found, after careful examination, that the prism should be sent away to be re-annealed.

An attempt was made to photograph the *Leonid* meteors on November 13. A plate was exposed in the focus of the 20-inch reflector which was directed towards the radiant point, and a camera of $1\frac{1}{2}$-inch aperture and 8-inch focal length, was also mounted at the eye-end of the reflector. During the greater part of the night the sky was overcast, and although one bright meteor did pass the field, there was no trace of it on the plates. Next year a camera with a lantern lens will be tried.

The time-service and the extensive meteorological work have been carried on as in former years.

Liverpool Observatory.

The work of the Observatory for the last year has mainly followed the lines indicated in the last report. The testing of chronometers and other scientific apparatus deposited by the public, and the determination and distribution of time form much of the routine work of the Observatory. The errors of the transit instrument, which had become inconveniently large, have been reduced by rubbing down the Y plates in a manner suggested by Mr. Simms. The method was perfectly successful, and the errors remained small throughout the autumn. They have since shown a tendency to increase, and the greater part of that increase occurred immediately after a slight shock of earthquake on December 17. Slight improvements have been made in the chronographic registry apparatus. No alterations have been made in the other astronomical instruments.

The comet observations of 1895 have been published in the *Monthly Notices*, and those for 1896 will shortly be submitted to the Society. The observations of the diameters of the larger planets, with different micrometers, and under different conditions of illumination, have been continued from time to time, but the observations have been much interrupted by bad weather.

The report of the Director to the Mersey Dock and Harbour Board, consisting mainly of meteorological observations, has been printed and circulated during the year. Considerable attention has been given to improved meteorological observations, and a new anemometer was erected in the summer.

Courses of lectures have been given regularly in connection with the classes at University College, Liverpool, and opportunities have been given to the students for practical work with the transit instrument and equatorial. These classes have been fairly well attended.

Radcliffe Observatory, Oxford.

The work at the Observatory during the year 1896 has included the following :—

The Sun and Moon have been observed with the transit circle at every available opportunity; seven observations of Comet Swift (1896 April 13) and one of Perrine (1896 Dec. 8) have been secured with this instrument; and the positions of several stars which could not be found in recent catalogues, but which were required for the reduction of the comet observations, have also been obtained with the transit circle.

The observation of a zone of stars to the north of the equator has been commenced during the year. This work is in continuation of that of the Radcliffe Catalogue for 1890 and the Cape Catalogue, 1880.

The Working Catalogue also includes a selection from a list of 834 zodiacal stars published as an appendix to the *Nautical Almanac* for 1897, observations of which are requested for the use of the *N. A.* office.

As the pivot error of the Radcliffe transit circle had not hitherto been satisfactorily determined, an interference apparatus, described by M. Hamy in the *Comptes Rendus*, was constructed and used for testing the form of the pivots. This apparatus is exceedingly delicate in its test, and showed that any existing errors were so small as to be practically insensible (see *Monthly Notices*, 1896 March).

An improved method of illuminating the wires of the transit-circle eyepiece has also been devised and mounted during the year.

The Barclay equatorial has been chiefly employed in the observation of comets :—

Perrine (1895 November 16)	on 1 night
Perrine-Lamp (1896 February 13)	„ 8 nights
Swift (1896 April 13)	„ 12 „
Sperra (1896 August 31)	„ 1 night
Brooks (1889 V.)	„ 1 „
Perrine (1896 November 2)	„ 6 nights
Perrine (1896 December 8)	„ 2 „

Besides these, rough positions were obtained, when the faintness of the object, cloud, or other adverse conditions prevented a perfectly satisfactory observation being made :—

Swift (1896 April 13)	on 2 nights
Giacobini (1896 September 4)	„ 3 „
Sperra (1896 August 31)	„ 1 night
Perrine (1896 November 2)	„ 2 nights

Searches for comets were made on eighteen nights, when the observers failed to pick them up.

The Barclay telescope has also been used for the examination of the great nebula of *Andromeda* ; for the determination of the position of nebula Herschel 544 ; a cluster of stars (R.A. $19^h\ 0^m$, N.P.D. 99° 30′) ; comparison stars for comets ; and for the estimation of the magnitudes of a deep-red star and some suspected variables.

The eclipse of *Jupiter's* fourth satellite (disappearance) was observed on April 13 by three observers ; the occultation of *Jupiter* by the Moon was seen by two observers, but the objects were very low and the definition poor.

The total eclipse of the Sun was successfully observed by Mr. Stone at Novaya Zemlya. The details of the expedition and subsequent discussion of the observations have been already communicated to the Society.

Tables have been prepared for facilitating the correction of the reduction of apparent places of stars to mean places for the interval between the time of observation and the nearest Greenwich mean midnight.

The meteorological observations and automatic registrations have been maintained as usual.

A Callendar-Griffiths temperature bridge and four platinum thermometers have been recently procured from the Cambridge Scientific Instrument Co., and the thermometers have been sunk to the respective distances of 6 in., 1 ft. 6 in., 3 ft. 6 in., and 5 ft. 10 in. below the surface of the ground.

The volume containing the Radcliffe observations made in the years 1888–89 was distributed during the spring of the year.

University Observatory, Oxford.

During the year 1896 attention has been paid chiefly to the measurement and reduction of the Catalogue plates for the Astrographic Chart. It seems clear that this is the most pressing part of the work, and the taking of new plates has not been pushed forward, so that more time might be given to the measurement and reduction of those already taken. The plan of procedure may now be regarded as settled and the work is proceeding rapidly. Application was made to the Government

Grant Committee in 1895 January for 150*l.* for the expenses of this work for one year, with the intimation that if the application were favourably considered it would be repeated for five years altogether. The first application was granted, and four boy computers are now engaged on the work; two micrometers are at present in use, and two more have been ordered from Messrs. Troughton & Simms, when it became clear that these could be used with advantage. This labour and apparatus has only, however, been available during a part of the year, which may be estimated as equivalent to one half.

The plates are each measured twice by the same observer, being rotated 180° in position-angle between the two measurements. The numbers expressing the rectangular co-ordinates of the stars in the second position are thus the arithmetical complements of those in the first. They are made comparable with the first by subtracting them from 26·000. A second computer performs this subtraction independently and compares the measures in the two positions. In this way he finds three kinds of discordances :—

1. Stars measured on the first occasion (D) and omitted on the second (R).

2. Stars measured on the second occasion (R) and omitted on the first (D).

3. Discordances of measurement, *i.e.* differences between the measures exceeding 0·005 of a réseau interval, or 1″·5. Forming a list of these, he calls upon the measurer for measures R of the first set, measures D of the second, and remeasures R and D of the third. This affords a valuable and practically complete check upon the results. The normal differences also show the "error of bisection" in measurement, which is eliminated from the mean of the two sets. The following tabular statement (of a portion of the work only) gives an idea of the quantities involved :—

Measurer.	Total No. of Stars.	No. Missed in R.	No. Missed in D.	No. of Discordant Measures.	Twice Error of Bisection (D−R)	
					x	y
					″	″
B	1968	91	193	114	+0·33	+0·24
F	2027	116	118	166	−0·12	+0·30
H	2128	114	125	233	−0·03	+0·09
C	2044	103	84	155	−0·33	0·00

Assuming that the "error of bisection" is eliminated by taking the mean of the two measures, we can proceed to determine the systematic error in R.A., depending on the magnitude of the star for the Cambridge meridian observations, which supply the fundamental stars of reference for these plates; and this discussion will shortly be undertaken.

The number of catalogue plates taken during the year is 168, bringing up the total to 777. In the "direct" or "D" position 135

plates (containing 22,601 stars) have been measured, and 80 (containing 11,652 stars) in the "R" position. Two thirds of the measuring has been accomplished since August 29, when two micrometers became continuously available. One of the micrometers was taken by the Director to Paris for exhibition to members of the Comité Permanent at its meeting in May, and was left at the Paris Observatory for experiment, by request. It had, however, been somewhat shaken by the journey, and did not perform so well as it might have done. By request of the Comité, the Director measured some stars on one of the Paris photographs, and the Comité was favourably impressed with the rapidity with which these measures could be made.

The advance proofs of the remainder of the Cambridge Catalogue ($5^h - 24^h$) have been received from Sir Robert Ball, and the places brought up from 1875·0 to 1900·0. A complete copy of the places for 1900·0 (14,500 stars) has been furnished to the Cambridge Observatory, by request.

Tables for converting the R.A. and Dec. of these stars into standard coordinates for zones $+25°$ to $+31°$ have been made, and the conversion of the stars in zone $+26°$ is completed and nearly examined, while that of stars for zone $+27°$ is well advanced. The zone $-25°$ is that of overlap between Cambridge and Berlin. 2,224 stars in the Berlin catalogue of declination greater than $+23°\ 45'$ have been brought up to 1900·0.

An effort will be made to complete the measurement and reduction of zones $+26°$ and $+27°$ before the end of 1897.

Lectures on elementary mathematical astronomy were delivered in the Hilary and Michaelmas terms. Several students have worked at practical astronomy in the Observatory.

The Director went to Japan during the summer for observation of the Total Solar Eclipse of August 9; but clouds prevented observations.

Temple Observatory, Rugby.

The usual educational work has been carried on during the past year at this Observatory, and an increased interest has been shown on the part of the boys.

The work of measuring double stars has been continued as usual, and a considerable number have been observed.

Some microphotography has also been done by Mr. K. Lucas at this Observatory.

Stonyhurst College Observatory.

The work of this Observatory during the past year has been the same as described in *Monthly Notices*, Feb. 7, 1896. The continuous photographic records of meteorological and magnetic changes have been broken only by occasional troubles with the gas supply.

The vertical force needle of the magnetographs was, however, dismounted between March 10 and June 23, and some experiments were made with the hope of improving its behaviour, but without any satisfactory results. The agate knife-edge and rest seem to be as good as can be made; but we are unable to place confidence in any numerical measures given by it, because it is apt to move by jerks, and does not safely return to its original position after deflection by another magnet.

About 130 photographs of the H–K region of the solar spectrum have been obtained with integrated solar light. These have not been fully examined yet, but, so far, it seems probable that the fine reversal of K has been either non-existent or very feeble.

Over 350 plates have been exposed for stellar spectra. These include some trials with the very small dispersion of a single half prism for the sole purpose of finding the condition of the K line in a star spectrum. The results of these experiments have not been very satisfactory; the definition is only such as to differentiate between a very strong, a medium, and a thin line; but it cannot decide upon the absence of the line. It does, however, show the line in stars to the 6th magnitude.

Dr. Common's Observatory.

Experiments with the oblique Cassegrain telescope were discontinued, and the direct Cassegrain form has been tried. The 5-foot mirror (C) has been reground under new conditions, with great improvement to the figure; two 30-inch concave mirrors for Cassegrain telescopes have been made, and two 16-inch and two 18-inch convexes for the 5-foot.

Some time was spent in preparations for observing the Total Solar Eclipse of August 9, and in going to Vadsö to observe it.

The 5-foot telescope is at present fitted up with a 30-inch Cassegrain telescope inside, but the bad weather during the winter has prevented any regular work.

The experiments referred to in the report for 1891, on the comparative reflective powers of silvered glass and speculum metal, &c., which were never completed, have been taken up again.

Mr. E. Crossley's Observatory, Bermerside, Halifax.

The work at this Observatory during the year 1896 differed little from that of previous years. Much time was devoted to observations of the planet *Jupiter*, and the results have already appeared in the Society's *Monthly Notices*. The usual meteorological observations were made, and monthly or annual summaries sent to the Registrar General, Mr. G. J. Symons, and others.

In June the old 9$\frac{1}{8}$-inch object-glass was replaced by one of Messrs. Cooke's new triple lenses of 9-inch aperture and 152 inches focal length. It has not yet been tested photographically, but in other respects has answered our expectations to the fullest extent.

Dr. Huggins's Observatory, Upper Tulse Hill.

The new spectroscopes which were in course of construction for the ultra-violet region have been completed during the year, and have been put into a state of adjustment. A series of star photographs has been begun with special reference to the region in the ultra-violet at and beyond which the absorption of glass comes in seriously. This work, together with some special lines of research, is being carried on whenever the weather is favourable. Unfortunately, the continuance of bad weather since November has been all but uninterrupted.

Rousdon Observatory, Lyme Regis. (*Mr. C. E. Peek's.*)

The building and equipment of the Observatory has been maintained in its usual order, and the weather has on the whole been very favourable for astronomical observation; 170 nights were available for work. The 6·4-inch equatorial refractor has been kept at the regular observation of long-period variable stars on the same lines as during the previous ten years, and 535 determinations of magnitudes have been made. Twenty-three maxima and eighteen minima have been observed. Twenty-five long-period variables are under regular observation, and being mostly circumpolar, the light variations are continuously recorded.

Transits of stars for time have been observed as often as required, and the sidereal clock has maintained a very steady rate.

The occultation of *Jupiter* and his satellites was observed on June 14 under very favourable conditions.

Dr. Isaac Roberts's Observatory, Crowborough Hill, Sussex.

The opportunities for taking photographs with long exposures of the plates have during the past year been comparatively few in number, and one is tempted to reiterate the assertion that the climate, for clear skies at nights, is in this country deteriorating.

The work done here during last year will be estimated by the following list of photographs which have been taken, and it is

given in continuation of similar lists which have been published in the *Monthly Notices*, vol. lvi. pp. 239–241, and in previous years. The photographs are available for reference, as also are those taken in former years.

	R.A. h m	Decl. ° ′	Expos. m
Cl. H VI. 35 Cassiopeiæ	0 25	+60 56	60
Great Nebula in Andromeda ...	0 36	+40 30	4[h]
Neb. H V. 25 Ceti	0 41	−12 27	90 and 2[h] 55[m]
Nebula in Cassiopeia	0 47	+56 2	2[h] 54[m]
Neb. H II. 215 Andromedæ ...	1 1	+31 57	90
Neb. H I. 54 Andromedæ	1 2	+39 5	86
Neb. H I. 157 Trianguli	1 42	+26 55	90 and 2[h] 55[m]
Neb. H I. 62 Ceti	1 46	−10 14	90
Neb. H III. 162 Trianguli	2 37	+31 59	90
Nebulæ in the Pleiades	3 40	+23 46	92 and 2[h] 50[m]
Nebula in Perseus	3 56	+36 8	90
Great Nebula in Orion	5 30	− 5 27	90
Neb. near ζ Orionis	5 35	− 2 0	90
Cl. H VIII. 33 Monocerotis ...	7 3	−10 29	60
Cl. M. 48 Monocerotis	8 8	− 1 38	60
Cl. Præsepe Cancri	8 34	+20 19	80
Neb. H I. 3 Sextantis	10 8	+ 3 57	90
Neb. H I. 266 Ursæ Majoris ...	10 15	+57 28	90
Neb. *h* 705 Leonis	10 18	+13 5	90
Neb. H I. 267–8 Ursæ Majoris ...	10 49	+57 36	50
Neb, H I. 220 Ursæ Majoris ...	11 5	+53 57	90
Neb. H I. 270–1 Ursæ Majoris ...	11 12	+58 58	90
Neb. H I. 226 Ursæ Majoris ...	11 15	+53 46	90 and 2[h] 49[m]
Neb. H I. 252–3 Ursæ Majoris ...	11 56	+62 36	90
Neb. H I. 224, 206 Ursæ Majoris ...	12 0	+51 2	65 and 2[h] 50[m]
Neb. M. 98 & 99 Virginis	12 11	+15 15	2[h] 57[m]
Neb. M. 100 Comæ	12 17	+16 24	2[h] 55[m]
Nebulæ in Virgo	12 30	+13 0	90
Neb. H V. 24 Comæ	12 31	+26 34	2[h] 53[m]
Neb. M. 64 Comæ	12 51	+22 15	2[h] 56[m]
Neb. H I. 96–7 Canum Venatic. ...	13 7	+37 23	62
Neb. M. 64 Canum Venaticorum ...	13 11	+42 35	2[h] 55[m]
Neb. M. 51 Canum Venaticorum ...	13 25	+47 45	2[h] 25[m]
Neb. H I. 255–6 Draconis	13 46	+60 53	90
Neb. H I. 237 Draconis	14 29	+58 23	90

	R.A. h m	Decl. ° ′	Expos. m
Neb. H I. 189 Boötis ...	... 14 29	+49 56	90
Neb. H II. 756 Boötis ...	... 14 55	+54 19	90
Neb. H II. 751–2 Boötis ...	... 15 2	+20 0	65
Neb. H II. 757–9 Draconis ...	... 15 13	+56 43	62
Neb. H VI. 41 Draconis ...	... 17 33	+75 48	2^h
Cl. M. 25 Sagittarii	... 18 25	−19 1	60
Cl. M. 11 Antinoi	... 18 46	− 6 24	90
Hind's Neb. in Aquila ...	... 19 6	+ 0 52	90
Cl. H VI. 38 Aquilæ	... 19 26	+ 9 0	2^h
"Dumb-bell" Neb. in Vulpecula	... 19 55	+22 25	2^h 55^m
Neb. H IV. 76 Cephei ...	... 20 33	+59 47	2^h 55^m
Neb. H V. 15 Cygni	... 20 42	+30 20	2^h 18^m
Neb. H V. 14 Cygni	... 20 52	+31 4	2^h 31^m and 2^h 55^m
Neb. H V. 37 Cygni	... 20 55	+43 55	90 and 2^h 55^m
Cl. H VI. 24 Cygni	... 21 9	+42 3	90
Cl. H VI. 29 Cephei	... 22 11	+53 48	43
Neb. H I. 104 Aquarii ...	... 23 13	− 9 3	90 and 2^h 53^m
Neb. H I. 110–111 Aquarii ...	... 23 34	−13 12	62

Mr. Wilson's Observatory, Daramona, Streete, co. Westmeath.

During the past year an optical method has been tried for detecting any shift that may take place in the 24-inch mirror while it is being used for stellar photography. The apparatus seems to work very well.

Professor Minchin again used the 24-inch to determine the electromotive force of the light of some of the stars with his photo-electric cells, the results being published in the *Proceedings* of the Royal Society.

The radiation of heat from sun-spots has been continued whenever spots of suitable size have been seen on the disc.

A series of experiments have also been carried out on Solar Radiation with Stewart's Actinometer for a committee of the British Association.

An investigation in conjunction with Professor G. F. Fitzgerald has been made in order to determine if carbon is raised to its boiling-point in the electric arc.

The results have been published in the *Proceedings* of the Royal Society, and seem to show that carbon may possibly exist in the Sun's photosphere in the solid form.

Adelaide Observatory.

During the past year the Observatory has been very short-handed, and the work has not only had to be curtailed, but has fallen somewhat into arrears. At the end of January Mr. W. E. Cooke, M.A., the first assistant, left Adelaide to take charge of the new Observatory to be established at Perth, and on July 25, the establishment sustained a great loss in the death of the third assistant, Mr. E. P. Sells, whose health had long been failing. Mr. R. F. Griffiths, second assistant, succeeded Mr. Cooke, but there are still two vacancies, one of which will be filled by the appointment of Mr. S. W. Chettle, Mr. W. R. Wilson succeeding Mr. Sells as second assistant. The actual working staff in 1896 consisted of Mr. R. F. Griffiths, Mr. W. R. Wilson, and Miss M. E. Greayer.

With the transit circle the only regular work undertaken has been the continuation of the observation of stars for the Melbourne Photographic Durchmusterung; 788 observations of R.A. and a similar number of observations of N.P.D. have been made during the year of this list, besides 1,030 clock stars, and for instrumental corrections,

101 readings of collimation,
187 „ „ level,
159 determinations of azimuth.

Nadirs are taken immediately before and after the observations every clear night.

Owing to the reduced staff no regular work could be done with the equatorial. Advantage was taken of a visit to England by Mr. Cooke, to get him to select and have put in hand the best form of micrometer for the equatorial. This is now being made by Troughton & Simms.

The meteorological work of the Observatory, which forms the bulk of the annual volume, is fairly well up to date. Daily forecasts are issued and published at nearly every telegraph station, whilst at Adelaide and a few other principal offices maps are posted showing distribution of pressure, direction and force of wind, also reports on the general state of the weather, pressure, temperature and rainfall over Australia and New Zealand. The volume for 1893 has been published during the year, and those for 1894 and 1895 are now passing through the press. It is hoped shortly that a number of excellent sketches of Jupiter, by the late Mr. Sells, will be published, with notes on the physical appearance of the planet.

In 1896 January the Director visited Perth, by desire of the West Australian Government, to select a site for the new Observatory, which he fixed on Mount Eliza.

Hong Kong Observatory.

Hourly observations and continuous meteorological records, weather forecasts, storm-warnings, magnetic observations, and the public time-service have been continued as usual. All the typhoons that have appeared since the beginning of 1884 (about 300 in number) have now been investigated, and the tracks published in the *Observations and Researches made at the Hong Kong Observatory*, of which the twelfth volume has been published. A few observations of double stars and shooting stars have been made. Orbits of *η Coronæ*, *ζ Herculis*, and *μ^2 Boötis* have been determined by the method of least squares. A standard catalogue of 100 pairs of zenith stars has been constructed by aid of the latest and best catalogues, especially the Greenwich Ten-Year Catalogue. These pairs of stars have been observed in the transit-instrument according to Talcott's method in order to determine the latitude and its changes, and eventually the solar parallax through the constant of aberration.

The Observatory, Nungumbaukum, Madras.

During the past year the work of reducing the old observations has made considerable progress, and if no unforeseen delays occur the final catalogue for 1875·0 should be completed this year.

The investigation of the division errors of the meridian circle has been completed. A number of determinations of flexure have also been made, as the adopted value seemed based on too small a number of observations, especially as these varied largely amongst themselves.

At the close of the year a series of latitude observations were in progress in conjunction with Captain Burrard, R.E., of the G. T. Survey of India, with a view of tracing the cause of the difference between the values of the latitudes obtained by observations of circumpolar stars and observations made with the zenith telescope.

The building of the new observatory at Kodaikanal has not yet been begun, but all the plans and estimates have been completed and a certain amount of material has been collected. Sanction has also been obtained for the necessary apparatus, and contracts have been entered into for the construction of the chief instruments.

Melbourne Observatory.

Astronomical.—The following observations were made with the 8-inch meridian circle :—

Observations in R.A. clock stars	728
„ „ R.A. list stars	1,092
„ „ R.A. azimuth stars	233
Total	2,053
Observations in N.P.D. list stars	1,101
Observations for level	123
„ „ collimation	120
„ „ flexure	11
„ „ runs	45
„ „ nadir	116

The "list stars" are stars selected from the Astrographic catalogue plates (five from each plate), to be used as fundamental points in the reduction of the negatives.

The separate results and annual catalogue of stars observed in 1895 were prepared and completed.

Of the stars observed in 1896, the greater part are finally reduced, and the separate results and annual catalogue for 1896 are in course of preparation.

Astrographic.—Catalogue plates exposed	129
Plates on south pole for testing the transparency of the night	25
Plates for star trails	20
„ „ adjustment of centre	12
„ „ Oxford type regions	11
Chart plates set on odd degrees of declination	47

One picture of 47 *Toucani*, exposure three hours; taken at the request of M. Hansky, of the Poulkova Observatory.

The plates rejected on account of deficiency of sensitiveness, broken exposure owing to clouds, defects in the film, inaccuracy in setting, or other maladjustments, as follows :—

Catalogue plates rejected	5
Chart plates rejected	5

The exposures of catalogue plates were invariably 5^m, $2\frac{1}{2}^m$, and 20^s, and for chart plates one hour.

All catalogue plates subjected to the same preliminary examination as in previous years.

Time Service.—The time-ball was dropped at Williamstown

at 1 o'clock statute time on 300 days, and time signals were sent throughout the colony at the same time daily, Sundays excepted. Seven failures occurred in the dropping of the time-ball, chiefly owing to accidental defects on the line.

Magnetical.—Photographic registration of the magnetic elements was carried on without interruption. Absolute measurements of magnetic declination, inclination, and horizontal component were made 12 times. The value of scales and of ordinates on photographic curves, &c., for the self-registering instruments, were made in March. Eye-observations of the variation in magnetic declination and horizontal component, at intervals of 5 sec., for periods of one hour at a time, were made at the request of Professor Bezold, of Berlin, in February and March last.

Meteorological.—The weather forecast was issued daily, Sundays excepted. Daily distribution of rainfall was prepared for the information of the public from records at 75 stations. Monthly statistics of rainfall and other meteorological elements, based on monthly returns from 540 stations, were prepared and published as usual.

Miscellaneous.—Rating of chronometers and testing of nautical and meteorological instruments for the public, at fixed charges, have been carried on as in previous years.

Special Cloud Observations.—This work was undertaken at the request of the International Meteorological Committee. Some 30 special volunteer observers were selected in various parts of the colony for observations of cloud form, direction of motion, and apparent velocity. They commenced their task on May 1, and will continue until the end of the year.

Also two stations (one of which is on the Melbourne Observatory grounds), situated at a distance of 6,820 feet from each other, were fitted for the purpose of determining absolute heights and velocity of clouds, by photographs taken simultaneously, with heavy metallic cameras permanently fixed on masonry piers, and with their optical axes pointing accurately to the zenith (Kew method). The work has just been commenced, and will continue for twelve months.

General Remarks.—The plates of the astrographic catalogue are now practically complete. A few scattered ones (some thirty in all) require to be taken again, and this will only require on the whole a few hours' work.

The resolutions taken by the Astrographic Conference at Paris in May last have given a good deal of uneasiness, owing to the large number of fundamental stars to be observed with the meridian circle for the reduction of the catalogue plates, and the increased time of exposure for one-half of the chart plates.

It had been contemplated that six fundamental stars in each plate (including the guide star) would be sufficient for the catalogue, and that one hour might be reckoned as the limit of

exposure for all the chart plates, but now that some 3,000 or 4,000 stars must be added to the list, for observation with the meridian circle, and three exposures of 30^m each are to be adopted for one-half of the chart plates, it is doubtful whether the Melbourne Observatory will be able to accomplish its share of the work within a reasonable time, even under the most sanguine expectations of liberality from the Government of Victoria.

So far no addition has been made to the staff of the Observatory. The position of chief assistant is still vacant, and the duties of the institution in connection with the demands of the public are continuously increasing, so that it has been impossible to undertake any equatorial work, or to deal with and publish observations accumulated in past years.

In the Director's last report to the Board of Visitors, he asked for three assistants to be employed solely in the measurement and reduction of the astrographic catalogue plates, and another assistant for general duties, but this request has not yet been dealt with.

Perth Observatory, Western Australia.

This Observatory is not yet in working order. Mr. W. Ernest Cooke, M.A., was appointed Government Astronomer in February, and after discussing plans with the colonial architect, and making a few alterations in the meteorological arrangements, he was instructed to proceed to England to inspect the astronomical instruments then being constructed. The principal ones are an astrographic equatorial by Sir Howard Grubb, and a transit circle by Messrs. Troughton & Simms. The former is similar to those generally adopted for the Astrographic Chart—13 inches photographic, and 10 inches visual. Sir Howard Grubb is also constructing a 20-foot dome and a chronograph similar to that made by him for Dr. Gill, and regulated by his "Mouse" control. The transit circle is of 6 inches aperture, and promises to be an exceptionally fine instrument. In order to eliminate as far as possible irregular refractions due to differences of temperature in the immediate neighbourhood of the telescope, a transit-room, of Dr. Gill's proposed form, is being constructed (*vide* Introduction to Cape Catalogue, 1885). The walls and roof will be made of papier-maché fixed to a wooden skeleton, and protected from direct sunlight by iron louvres painted white, and the floor, of iron, will be raised three feet above the ground, leaving a space underneath for free circulation of air.

A number of meteorological instruments were also obtained, including six platinum resistance thermometers from the Cambridge Scientific Instrument Company, for registering earth temperatures, and for use in the openings of the transit shutters, if experiment proves their reliability for this purpose.

On his return, Mr. Cooke inspected all the meteorological

stations in the colony, establishing a few fresh ones, and supplying all with thoroughly reliable instruments. It is proposed to keep in touch with the observers by means of an annual inspection, and it is hoped that valuable meteorological information will shortly be available for this extensive territory.

Sydney Observatory.

Staff.—There has been no change in the astronomical staff, but the first assistant in the meteorological staff died on March 2, and the position has been filled by the promotion of Mr. H. A. Hunt to the position of first assistant.

Buildings.—The shutters of the large dome have been taken out and worn out friction rollers have been replaced by new ones. The shaft of the time-ball, which was made of wood, was found to be in a dangerous condition from decay, and has been removed and replaced by one made of iron. While these repairs were going on the time-signal was given by a temporary ball, erected on the tower three feet north of the permanent one. The wood-planking on the flat roof between the north and south domes, having become unsafe by decay, has been replaced.

Weather.—We have had another year of drought, and its usual accompaniments, dust, haze, and bad definition, have made it impossible to take measures of double stars, or photographs on many otherwise fine nights. This drawback affects the photographic work more seriously than it does the double star measures, for a slight haze suffices to produce a serious fog on long exposure chart plates.

Meridian circle.—With the meridian circle only 1,613 transits were observed; of these 470 were sun-transits. 1,034 north polar distances were observed, 66 determinations of the flexure of the instrument have been made at different temperatures, and the series is now complete. Azimuth was determined on 92 nights, collimation determined 290 times, level 377, and nadir 375 times. The precessions in R.A. and N.P.D. for all stars observed in 1893–94 and 1895 have been computed and lists prepared for press. The computations of stars observed in 1896 are well forward.

Equatorial.—Only 55 evenings were available for double-star measures, and 45 pairs have been measured, by 574 settings for position angles, and 646 for distances. Two evenings were devoted to the search for comets, and were unsuccessful; 24 evenings had to be given to visitors.

Star Photography.—Reference has already been made to the weather drawbacks affecting this work, and the fact that nearly every night was devoted to long exposure or chart plates will account for the comparatively small number of chart plates. The total number of photographs taken during the year was 375; of these 16 were for catalogue, 4 on special objects, and 355 for

chart. All but 20 were therefore long exposures of 30 to 45 minutes; the plates used being such as give a good image of an 11 magnitude star in one minute.

Meteorology.—The meteorological work has been carried on as usual, the steady increase in the number of stations being maintained. The volume for 1895 has been published, and that for 1896 is nearly ready for press.

General.—During the year 1,472 copies of publications have been sent out, and 962 publications received from other observatories. The number of visitors steadily increases, and, I fear, must continue to do so while the Observatory remains in the heart of the city. A very fine site for the Observatory has been selected out of the city, and ten miles farther from the sea. It has an altitude of 615 feet, and an effort will shortly be made to get the astronomical instruments removed to the new site.

Lovedale, South Africa. (*Mr. A. W. Roberts's.*)

The work here has been the regular observation of variable stars south of −30° Decl. Two new variables were discovered during the year, one in *Carina* and the other in *Centaurus*. The latter star belongs to Class II. type of short period variation.

Observations were made on 150 nights, the details of work being as follows:—

Algol variables (4 stars)	797	observations
Short period variables, Class I. (18 stars) ...	1,528	„
„ „ „ Class II. (1 star) ...	524	„
Long „ „ (29 stars)	1,002	„
Suspected variables (30 stars)	227	„
Total	4,078	„

Each observation is the mean of two others, one direct and the other reverse. In this way the chief possibilities of error in the determination of magnitudes by eye estimates—*viz.* mental bias and position error—were considerably reduced.

It is intended during 1897 to discontinue observations, to permit of a discussion of all the observations taken at Lovedale during the past six years, and also to make arrangements for a survey by eye estimates of the magnitudes of all stars between $6^{m}\cdot0$ and $9^{m}\cdot0$ south of −30° Decl.

Mr. Tebbutt's Observatory, the Peninsula, Windsor, N. S. Wales.

With the exception of the opening and closing months, the year 1896 has been characterised by clear skies, and as a consequence, an unusually large amount of both meridian and extra-

meridian work was done. The local sidereal time was determined on 221 nights, and for this purpose 1,485 transits of stars were observed. Of these transits, 1,230 were of stars with a declination not exceeding 40°, and 255 of stars in high declination for azimuth. The separate determinations for the level, collimation, and azimuth errors of the transit instrument were respectively 536, 54, and 237. Although the changes of azimuth were not great, it is interesting to note that the gradual falling of the eastern pivot during the year 1895 continued till the middle of February, when the apparently compensatory rise of the pivot began, and this continued right through the year.

The results in the extra-meridian department are about the richest obtained in any one year since the foundation of the Observatory. 161 phases of lunar occultations of stars were observed, mainly with the 8-inch equatorial. These comprise 132 disappearances at the dark, and 11 at the bright limb, and 12 reappearances at the dark, and 6 at the bright limb. Fifteen *Nautical Almanac* stars were observed in both phases. For the 161 phases, 109 stars have been identified, and the places of the remaining fifty-two stars were approximately determined at the time of observation. It is very desirable that some meridian observer should at once take up the observation of the fifty-two unidentified stars, so that in the utilization of the occultations at a future period all doubt as to proper motion might be avoided. During the past thirty-three years 853 occultations have been observed, and although the year 1895 was the record year in this department, presenting as it did sixty-five observed phases, it has been surpassed by that just elapsed. Mr. Joseph Brooks, F.R.A.S., during the year 1896, again kindly furnished the Observatory with predictions of occultations of *Nautical Almanac* stars.

The 8-inch equatorial has also done good service in the observation of minor planets. The following is a statement of the work in this department :—

Planet.	Nights of Observation.	No. of Comparisons.
Hebe (6)	11	162
Flora (8)	9	113
Parthenope (11)	18	196
Calliope (22)	8	84
Danaë (61)	7	75
Sappho (80)	3	34
Undina (92)	4	55
Siwa (140)	10	91
Totals	70	810

Hebe and *Parthenope* were observed at the request of Dr. Luther, of Düsseldorf, and *Calliope* and *Siwa* at that of Dr. Bauschinger, of Berlin.

There has been no comet sufficiently bright to be observed with the 8-inch telescope. Notice of the discovery of the comet *Perrine* was received on December 11, but cloudy weather prevailed till the 15th, when a search was made in the bright moonlight, but without success. A search was again made after the withdrawal of the Moon on the 22nd, but this was also unsuccessful.

The phenomena of *Jupiter's* satellites were closely watched and recorded during the first five months of the year. During the same period two remarkable dark spots were observed on the disc of the primary. Nine transits of one spot and seventeen of the other were observed across the central meridian of the planet. Ephemerides of these spots were likewise circulated from the Observatory in the hope that they might be independently observed elsewhere.

In consequence of the observer's close application to other departments of observation, much attention could not be paid to double-star work. Seven evenings were devoted to this work, during which 199 settings were made for position angles, and 153 double measures for distance. The following double stars were measured :—*p Eridani*, *Lacaille* 2145, *V Puppis*, *γ Piscis Volantis*, *γ Centauri*, *β Muscæ*, *α Centauri*, and *A Scorpii*.

In the variable star department a few observations of *T Centauri* and a well connected series of *R Carinæ* were secured. The latter star was compared with neighbouring stars on thirty-three evenings. Its maximum occurred about March 8 with a magnitude of 5·3 of the scale of the *Uranometria Argentina*. At the close of the year it was again approaching its maximum, the magnitude being estimated at 4·9.

The meteorological observations have been regularly made, and the summer of 1895–96 proved to be the hottest experienced since observations were commenced in 1863. On January 6, 12, 13, 18, the highest shade temperatures were respectively 116·5, 116·6, 118·4, and 115·9. Many deaths occurred in the colony from heat apoplexy. The excessively hot summer may be regarded as nature's compensation for the extraordinary cold winter of 1895.

In conclusion, it may be stated that the proprietor has made all the astronomical observations and executed fully three-fourths of the reductions. The greater portion of the meteorological observations and their reductions has also devolved upon him.

NOTES ON SOME POINTS CONNECTED WITH THE PROGRESS OF ASTRONOMY DURING THE PAST YEAR.

Discovery of Minor Planets in 1896.

Twenty-three new planets were discovered during the past year as follows :—

Provisional Designation.	Permanent Number.	Name.	Date of Discovery, 1896.		Discoverer.	Place of Discovery.
CH	410	...	Jan.	7	Charlois	Nice
CJ	411	...		7	,,	,,
CK	412	Elisabetha		7	Wolf	Heidelberg
CL	413	Edburga		7	,,	,,
CN	414	...		16	Charlois	Nice
CO	415	...	Feb.	7	Wolf	Heidelberg
CP	...	...	Apr.	2	,,	,,
CQ	...	...		21	,,	,,
CR	...	...		21	,,	,,
CS	416	...	May	4	Charlois	Nice
CT	417	...		6	Wolf	Heidelberg
CU	...	...	Sept.	3	,,	,,
CV	418	...		7	,,	,,
CW	419	...		7	,,	,,
CX	...	...		7	,,	,,
CY	420	Bertholda		7	,,	,,
CZ	421	Zähringia		7	,,	,,
DA	422	*Berolina*	Oct.	8	Witt	Berlin
DB	...	...	Dec.	7	Charlois	Nice
DC	...	...		28	,,	,,
DD	...	...		31	,,	,,
DE	...	...		31	,,	,,
DF	...	...		31	,,	,,

Planet CE, discovered 1895 December 9, has been numbered 409.

The planet provisionally designated CM proved to be identical with (332) *Siri*.

Planet 417 was independently discovered by Charlois on May 8.

The following planets have been named :—(324) *Bamberga*, (330) *Adalberta*, (337) *Devosa*, (338) *Boudrosa*, (340) *Eduarda*, (341) *California*, (342) *Endymion*, (343) *Ostara*, (345) *Tercidina*, (346) *Hermentaria*, (347) *Pariana*, (351) *Yrsa*, (352) *Gisela*, (385) *Ilmatar*, (391) *Ingeborg*. It will be recollected that the name *Ilmatar* had previously been given to another planet which was afterwards found to be identical with (298) *Baptistina*.

From some large discrepancies from theory in the motion of (151) *Abundantia*, Herr Groeben suggested in *Ast. Nach.* 3,372, that there might be two neighbouring planets travelling in almost identical orbits, of which sometimes one had been observed and sometimes the other. Herr Villiger, however, observed *Abundantia* in October last, and searched the neighbourhood for a companion planet without success.

M. Gustave Ravené has made an estimate of the mass of the entire group of minor planets (*Ast. Nach.* 3,356). He assumes that the excess of 5″ per century in the motion of the perihelion of *Mars* above its theoretical value is due to their action, and hence deduces that their total mass is $\frac{4}{3}$ of that of the Moon. Herr Harzer, however, considers that there is some error in his investigation, and that a mass eighteen times as great would be required to produce the observed effect.

Three investigations of the perturbations of minor planets by *Jupiter* have been published during the year. Herr Ludendorff, in *Ast. Nach.* 3,349, examines the motion of the outer members of the group, and gives tables for facilitating numerical computation.

Dr. Olsson and Dr. Martin Brendel examine (*Ast. Nach.* 3,357 and 3,346 respectively) the case of planets whose period is approximately commensurable with that of *Jupiter*.

The following planets have been observed at a second opposition since the date of the last Report :—309, 332, 339, 342, 356, 358, 364, 367, 385, 386, 391, 402, 405.

A. C. D. C.

The Comets of 1896.

Omitting mention of Faye's Comet, which passed through perihelion last March, but which was re-observed in 1895 September (see *M. N.* vol. lvi. p. 253), six comets have been certainly discovered during the year. Two or more suspicious objects, which have been seen only once, are not included in this summary.

The history of the first cometary discovery of the year is not a little curious. A telegram sent from Kiel to the Lick Observatory concerning the re-observation of Perrine's Comet of 1885 November after perihelion passage was incorrectly transmitted, and the place did not agree with the observations made at Lick

Observatory, where Perrine's Comet had been regularly observed since January 29. This confusion induced Mr. Perrine to examine the part of the sky indicated in the telegram, and there he found a comet, which he was enabled to announce as new, on February 14. On the following morning Dr. Lamp, of Kiel, independently convinced himself of the existence of a new comet. The two comets, both situated in *Aquila*, made the closest approach on February 16, when they were separated by rather more than two degrees. The new comet was brighter than the one of the previous year, and was moving rapidly north, but growing fainter, the perihelion passage having been passed on the last day of January. The elements do not greatly differ from a parabola. M. Schulhof's attempt to determine the eccentricity led to a hyperbola, but later deductions have not supported this view. The comet was photographed by MM. Josef and Jan Fric, in Prague. The most successful negative on February 22 shows a tail in position-angle 320° of two and a half degrees in length, with a dark line running through the centre.

Dr. Lewis Swift announced on April 13 the discovery of a comet which he had probably seen some days earlier, but of which he had been unable to recognise the true character. This comet was tolerably bright at the time of its discovery, but placed too near the horizon for favourable observation. As it moved northwards it diminished in brilliancy, and by the middle of June the comet had passed out of reach of all but the largest telescopes. Its short course is satisfactorily represented by a parabola.

The next discovery in point of time, though not in order of perihelion passage, was effected by M. Javelle, of the Nice Observatory, who, on June 20, successfully picked up Brooks' Comet of 1889 (see *M. N.* 1890, p. 218). The definitive elements of this comet, based on the observations of 1889, were deduced by Dr. Bauschinger, and the ephemeris that led to the discovery is also due to the same computer; but the calculation of the effect of perturbation on the circumstances of this return was made by Dr. Lane Poor, who was particularly interested in this comet on account of its possible identity with that of Lexell. That the orbit is fairly accurate is shown by the small difference that separates the observations from Dr. Bauschinger's ephemeris (24^s in R.A., and $2''.5$ in declination), indicating a passage through perihelion about one-fifth of a day later than that employed in the ephemeris. The smallness of this correction, pointing as it does to the accuracy of the original elements determined from the 1889 return, does not favour the probability of an identity between this comet and that of Lexell. To establish this identity very considerable perturbations by *Saturn* were needed, and this disturbance is not indicated. Moreover, the improved value of the mean motion, based, it must be admitted, on a very few observations, indicates an extremely close appulse to *Jupiter* in 1791, and such an appulse clearly indicates that the two comets are not one and the same. Unfortunately, the question is still further

complicated by the appearance that the 1889 comet presented. The principal nucleus was then seen to have several nebulous companions, and it is not impossible, owing to variations in brilliancy then noticed, that the observations at this return do not belong to the same nucleus as was then under observation. Companion comets have been looked for in the neighbourhood of the Javelle comet, but without success. This, however, may be due to the faintness of the nucleus at the present apparition. At the time of its greatest brilliancy, in September, it was beyond the reach of moderate apertures.

The fourth cometary discovery of the year was made by Mr. W. E. Sperra, of Randolph, Ohio, on August 31, but owing to difficulties of communication with Harvard, and some little delay at the Allegheny Observatory, the fact was not published till after the discovery had been repeated by Mr. Brooks, of Geneva, with whose name the comet was first connected. The comet was tolerably large and diffuse, and from its circumpolar position at the time it was first seen should have been very generally observed. But it remained a very faint and difficult object in ordinary telescopes, and by the end of September had practically ceased to be observable. The orbit, which is very nearly perpendicular to the ecliptic, is probably parabolic.

Pending the announcement of the Sperra-Brooks Comet, but subsequent to the actual discovery, M. Giacobini, of the Nice Observatory, detected a faint comet in the constellation *Ophiuchus*. This object proved itself still more difficult than the last, being less than two minutes in diameter and of considerable southern declination. But the orbit, though at present uncertain, is likely to prove very interesting from its elliptic character. The first ellipses computed gave a very short period, and, indeed, the early observations could be satisfied with a period of only 510 days. Later observations, carried on at Lick Observatory till the end of October, disclose, however, a period of nine years.

On November 2, Mr C. D. Perrine found another comet, making the fifth in the year. It was tolerably bright, but moving southwards towards perihelion, and at the beginning of 1897 is practically lost by proximity to the Sun. When again at a sufficient elongation for observation, it will be visible only in the southern hemisphere. The perihelion passage does not occur till next February, but the time of its maximum brilliancy is next April, when it will be six times as bright as when discovered, and probably be visible to the naked eye. It may be again observed in this hemisphere next summer.

The last comet of the year was also discovered by Mr. Perrine, on December 8. It was a tolerably bright telescopic comet, stated to be equivalent in brilliancy to a star of the eighth magnitude. This comet was also moving southward and diminishing in lustre, having passed its perihelion in November. The elements of the orbit are still somewhat uncertain, but the latest

discussion shows that the orbit is elliptical, and that the elements have some similarity with those of Biela's Comet.

In addition to this somewhat lengthy list, it should perhaps be mentioned that in 1895 December, M. du Celliée Muller, of Nymegen, announced to the editor of the *Astronomische Nachrichten* that he, in company with Herr G. J. Van Dyk, had discovered a comet quite close to *Venus*. This object was described as bright, with a tail inclined to the horizon at an angle of 35°. This comet has not been seen elsewhere, though sought for in various observatories; neither will the direction of the tail accord with the position of the Sun. M. Muller, however, insists on the impossibility of his being mistaken. In connection with this rather doubtful observation may be mentioned another, reported by Dr. Lewis Swift, of one or of two comets which he, in company with fifteen other persons, saw near the Sun on September 20. This observation has not been verified. On September 21, Dr. Swift reports that he, with a small telescope, saw one comet only; but no place is given. W. E. P.

Progress of Meteoric Astronomy in 1896.

January and April Meteors.—Very little was observed of these displays owing to moonlight and cloudy weather. Prof. Herschel, however, watched for meteors on several nights between April 9 and 22, and registered 35, of which about 6 were *Lyrids* from a radiant indistinctly marked at 275° + 38°, and 5 from a bordering shower of *Draconids* at 270° + 48°. Other radiants were indicated at 257° + 62°, 209°—7°, and 213° + 52°.

August Meteors.—These were fairly well seen at several stations on August 10, but the display was not an abundant one. At Bristol, during the interval of $4^h\ 25^m$ from $9^h\ 50^m$ to $14^h\ 15^m$, 98 shooting stars were seen, of which 69 were *Perseids*, from a radiant at 45° + 57°. Mr. Blakeley, of Dewsbury, counted 35 *Perseids* between 11^h and $12^h\ 30^m$, and they gave a sharply defined radiant at 43° + 58°. Mr. S. H. R. Salmon, of Croydon, saw 20 meteors (15 *Perseids*) between $9^h\ 10^m$ and 10^h, and 18 meteors (16 *Perseids*) between $10^h\ 10^m$ and 11^h, the sky being perfectly clear. Mr. Corder saw 30 *Perseids* with radiant at 47° + 58°. On August 12 he counted the same number of *Perseids*, and fixed the radiant at 48° + 60°. Mr. Booth, at Leeds, watching the sky on August 11, 10^h to $10^h\ 45^m$, recorded 18 meteors, and found the *Perseid* radiant very diffuse, with a centre at about 47½° + 58½°. Mr. Milligan, of Belfast, noted 10 *Perseids* on August 5, from 37° + 57°, 22 on August 9, from 47° + 58°, and 8 on August 15, from 50° + 58°. From a comparison of the radiants determined on different dates, the shifting of the centre is shown in a very conclusive manner. Several *Perseids* were doubly observed and their real paths computed. On August 10, $10^h\ 6^m$, a bright meteor of

this shower was registered at Bridgwater and Bristol, and it traversed a course of 47 miles, descending from 75 to 49 miles over Reading to Southampton, with a velocity of about 32 miles per second.

November Meteors.—It was confidently expected that this shower would exhibit a very marked increase of strength this year, but, though observations were pretty numerous, it seems to have disappointed expectation. The *Leonids*, it is true, formed a well marked shower, but they may be said to do this nearly every year; on the whole, however, the display was certainly more actively defined than usual, though the horary number was only 8 or 10 at the richest time, viz. the morning of November 15. One observer, writing from Scotland, says there was quite a shower of meteors there—about 60 being counted—between $5^h\ 15^m$ and $5^h\ 45^m$ on the morning of November 15, but this report lacks confirmation. From America there are some doubtful descriptions of a fine shower, as many as 12 at a time being seen, and some were so large as to be visible at noonday. The following is a summary of some of the best observations to hand from English and continental observers:—

Date.	Hours of Observation.		Duration.	Meteors Seen.	Leonids.	Observer.
	h m	h m	h			
Nov. 12	...	...	2½	20	5	Corder
13	14 0	17 20	3¼	33	15	Corder
13	11 15	16 30	5¼	131	70	Riggenbach and 5 others
13	14 10	18 10	4	56	29	Anderson
13	12 0	16 15	4¼	40	12	Blakeley
13	13 55	16 55	3	22	15?	Martin
13	14 8	18 10	4	56	29	Anderson
14	12 0	18 0	6	46	34	Herschel
14	16 0	18 0	2	19	11	Denning
14	12 30	14 0	1½	15	9	Milligan
14	14 0	18 15	4	66	43	Corder
14	17 38	18 42	1	...	7	Besley
14	8 3	9 33	1½	27	12	Meares
14	13 40	17 49	3¼	25	23?	Martin
14	12 0	17 20	5	75	46	Thompson Tanner

Radiant Point.

148°+23°	Herschel	149°+22°	Besley
146+25	Corder (13th)	150+22½	Denning
150+23	„ (14th)	149+23	Milligan
150+24	Blakeley	152+21	Meares

Several *Leonids* and other meteors were doubly observed—two of the latter were from a radiant at 133° + 32°, and corroborate one of the many minor showers of the epoch. Another, seen on November 12, was from a radiant in the head of *Cetus* (45° + 4°), and was quite a brilliant object, giving a flash which lit up the sky ; but it appears to have been seen by not more than 3 observers. Of the lesser streams which always manifest themselves at the middle of November, Prof. Herschel re-observed three from the points 150° — 12°, 135° + 17°, and 155° + 35°. Summing up the results, it may be briefly stated that the *Leonid* shower of 1896, if not very rich, formed an interesting display, and gave promise of a returning strength which will be sure to be further developed in 1897. As to photographic methods, it does not appear that successful efforts have been made to determine the radiant.

December Meteors.—These formed an active display on December 11. Mr. J. Evershed, at London, watched the sky during the half-hour from $12^h\ 50^m$ to $13^h\ 20^m$ on that date, and counted 32 shooting stars, of which about 27 were *Geminids* from a radiant not well defined at 117° + 25°. "The meteors were rather swift, but without trails ; the brighter ones were a fine blue colour, and many fell apparently near to the horizon." Mr. D. Booth, at Leeds, saw about 20 *Geminids* on the same evening, and estimated their radiant as at 110° + 31°. At $12^h\ 24^m$ he recorded a brilliant meteor of the stream, about 2 × ♀, with a path from 55° + 35° to 25° + 25°. Prof. Herschel mapped nine tracks between $11^h\ 55^m$ and $12^h\ 25^m$ (rate of 18 per hour), when the sky clouded over. On December 12, 10 or 12 *Geminids* were mapped from 10^h to 12^h (rate of 5 or 6 per hour), showing the maximum certainly took place on December 11. Mr. Blakeley watched on December 11 for about 1 hour, and saw over 20 *Geminids* with a rather diffused radiant at about 110°+34°. Mr. Corder gives the following figures as the results of his observations at Bridgwater :—

Date.	Period of Watch. h m h m	Total No. of Meteors.	Geminids.	Radiant. ° °
Dec. 9	8 50 to 12 0 at intervals	39	22	111 + 34 115 + 32 103 + 34
11	10 0 to 15 0	112	89	110 + 34 112 + 30
12	14 0 to 16 15	30	21	111 + 33

Fall of a Meteorite at Madrid.—In the bright sunshine and blue sky of February 10, at $9^h\ 29^m\ 30^s$ A.M., a fireball of great lustre was seen at Madrid. It left a white streak about 6° long and 1° wide, a few degrees S.E. of the zenith ; it soon became

semicircular in form, and looked like a film of cirro-cumulous cloud. Ten seconds after the meteor flashed out there was a strong detonation, which lasted two minutes. The glass windows of some of the houses were broken by the vibrations. From the position of the meteoric cloud the body must have proceeded from S.E. towards N.W., and burst near the zenith of Madrid. It slowly drifted eastwards under the action of currents in the upper air, but was still visible at 3 P.M., 5½ hours after its first projection, when its position was 20° above the eastern horizon.

Some pieces of the meteor fell in the suburbs of Madrid. One fragment obtained by Signor Arcimis (to whose account in *Nature* for February 27 we are much indebted) was of a black metallic aspect; inside it was of a white stony appearance, with some brilliant points like nickel. It weighed 6·3 grams. The phenomenon was visible over a considerable region of the peninsula. An analysis of one of the stones has since proved it to consist of the silicate of magnesium and iron, containing also estimable quantities of aluminium, nickel and calcium.

Fireballs.—On March 16 $10^h\ 13^m$ a very fine meteor, leaving a train, was seen at Bridgwater and Stratford-on-Avon. Its radiant was in *Libra*, and the end point of its flight is indicated at a height of 29 miles above Llanfain, N. Wales.

On April 8 $8^h\ 20^m$ a meteor brighter than *Venus* was widely seen in England. Its course was from over the Straits of Dover to the south part of Leicestershire, and it descended from 65 to 38 miles. Length of observed path, 161 miles; velocity, 20 miles per second. Its radiant was in *Libra*, like that of the meteor of March 16.

On April 12 $8^h\ 6^m$ a large fireball, emitting sparks, was observed. One spectator estimated its brightness as twice that of the full Moon. A large number of observations were collected of this object, and it appears to have radiated from a point near α or ζ *Persei*. When first seen, it was 118 miles high over Formby, and at its disappearance was 34 miles high over Doddington, Cambridgeshire. Real length of path, 177 miles, and velocity, 19 miles per second.

On September 10 large meteors were observed at $9^h\ 3^m$ and $10^h\ 26^m$. The first was brighter than *Venus*, and left a long streak for about 30 secs. It had a radiant in *Auriga* at $72° + 42°$, and fell from 82 to 65 miles over the Irish Sea. The second was many times brighter than *Venus*, and had a radiant near β *Cephei* at $330° + 71°$. It fell from an elevation of 71 to 30 miles above Herefordshire.

On November 12 $11^h\ 8^m$ a fine meteor was seen at Reading and Cardiff. It appears to have had a radiant at $45° + 4°$ in *Cetus*, and to have fallen from 52 to 29 miles.

Association of Comets and Meteors.—Considering the large number of computed orbits of comets and of meteoric streams, surprise has occasionally been expressed that very few satisfac-

tory instances of connection have been detected between them. When, however, it is remembered that comparatively few comets pass near the Earth, the rarity of such accordances will be easily understood. Professor A. S. Herschel recently consulted Galle's Catalogue of Cometary Orbits to 1893, to ascertain if any resemblances could be discovered between recent comets and meteoric systems. The result of his examination is curious and surprising, for during the last 20 years only two observed comets (among upwards of 80 newly-discovered comets) have approached the Earth's orbit pretty closely. These were 1881 V. (Denning) and 1886 VII. (Finlay). The former approaches us within ·032 of the Earth's radius vector, while the latter passes it within ·05. These values correspond to distances of about 3,000,000 and 4,600,000 miles respectively. Comet 1881 V. would have a radiant point on December 14 at 277°–34°, near ϵ *Sagittarii*, but as the Sun is in long. 262° on that date, the radiant sets with the Sun, and thus the meteor shower, if any, is practically extinguished by daylight. Comet 1886 VII. has a radiant on October 5–6 in the head of *Sagittarius*, and its position enables it to be well visible in the early evening hours; but no meteoric shower has ever been observed from *Sagittarius* in October. It might be well to look for such a display, however, when the comet is near perihelion, as in 1899 October. But the nearest approach of the orbits of the Earth and comet may not be sufficiently close to originate a meteoric shower. Comet 1866 I. (Tempel), which produced the brilliant *Leonid* display of that year, passed within ·017 of the Earth's orbit, or at a distance of about 1,600,000 miles, which is about one-third of the interval separating us from the orbit of Comet 1886 VII. (Finlay) at its nearest point.

Among the recently published contributions to meteoric literature may be mentioned *Meteors and Sunsets*, forming No. 5 of the Lick Observatory publications. This work contains a discussion of the observations of the fireball of 1894 July 27 by Professor E. S. Holden, also observations of the *Perseids* by Messrs. Schaeberle, Colton and Perrine. The British Astronomical Association's Annual Report on Meteors was issued in 1896 June, and contains a mass of interesting details of recent observations by Members of the Meteoric Section. In the *Astr. Nach.* 3,360 (1896 June 15) Dr. Doberck gives a catalogue of 31 radiants observed at Hong Kong in the years 1891–5.

W. F. D.

Solar Activity in 1896.

A further decline in the general activity of the chromosphere is shown by the 1896 observations. Taking the year as a whole, the mean activity with regard to prominences has diminished by about 30 per cent. as compared with the previous year. A well-marked minimum occurred in April and the first half of May,

when at times the chromosphere appeared almost entirely undisturbed. Excepting this period, however, prominences have been tolerably abundant throughout the year in equatorial and mid-latitudes; the parallels ± 55°, as in 1895, marking a pretty definite limit in the distribution. The polar regions have been practically inactive.

The general distribution again clearly negatives any direct connexion between the ordinary type of prominence and faculæ. Professor Tacchini's results for the first six months of the year show that prominences have been about equally numerous in the two hemispheres, from the equator up to latitude ± 50°; whilst the faculæ have been most frequent south of the equator with maxima in the zones ± 10° to 20°.

Of the total number of prominences of all kinds observed at Kenley and Sevenoaks, 2·3 per cent. reversed the sodium and magnesium lines; whilst the helium line at W. L. 6678 and the corona line (5316) were each recorded once only. These metallic prominences were found in the regions + 6° to + 33° and − 9° to − 40°, and were most frequent in the southern hemisphere, closely corresponding therefore with the faculæ and spots.

Reversals and distortions of the hydrogen lines on the Sun's disk have accompanied certain spot groups, notably on June 11, 12, and 13 in latitude − 16°/21°, on July 14, 17, and 20 in latitude − 19°/25°, and in the great group of September, on September 16.

No records of eruptions on a large scale have been received.

So far as the numbers and areas of sun-spots are concerned, the decline in the solar activity recognisable in 1894 and 1895 became very marked in 1896. For the first time since 1891 March 28 there were days when the disk was entirely free from spots, four such instances being recorded during the months of April and May. And the general decline in the mean daily spotted area was most considerable, both Professor Tacchini, at Rome, and M. Guillaume, at Lyons, giving the value for 1896 as but three-fifths of that for the preceding year, a value in close accord with that derived from the photographic record at Greenwich, so far as that is yet complete. The decline in the area of the faculæ has, however, been much less pronounced, the figures given by M. Guillaume showing a falling off in the year just past of about 28 per cent., whilst Professor Tacchini even records a slight recovery.

As to distribution in latitude, both spots and faculæ show a well-marked preference for the zones 10° to 20° on both sides of the Equator; the slight predominance shown by the northern hemisphere in 1895 has now disappeared, and the southern is once again distinctly the most prolific both for spots and faculæ.

Little change seems to have taken place in the mean latitude of the spots; the general tendency is for the mean latitude to slightly decrease, and spots above 20° have been rare. On the other hand, M. Guillaume has recorded two instances of very small short-lived spots in latitudes of 44° and 47°.

The most remarkable spot-group of the year was that of September 10–22. It attained a maximum area of 2,000 millionths of the Sun's visible hemisphere, but its chief characteristic was its unusual length, extending as it did over 24° of solar longitude, the various spots which made up the stream following each other, during the earlier days of its appearance, so closely as almost to form one continuous rift.

Total Solar Eclipses.

1893 *April* 16.—Since the date of the last report, two additional papers have been published on this eclipse.

M. Deslandres has collected the report and discussion of his observations into a volume published by the Bureau des Longitudes (*Observations de l'éclipse totale du Soleil du 16 avril 1893*). This volume adds little to what has been already discussed by M. Deslandres in the *Comptes Rendus*, but there is one point that we may mention. This is with reference to the supposed detection of the rotation of the corona. It will be remembered that by observation of the relative movements in the line of sight of the two parts of the corona, or opposite limbs of the Sun, as determined spectroscopically, it was claimed that evidence had been obtained showing that the corona partakes of the Sun's rotational movement. This deduction was made from measurements of photographs of the bright H and K lines, and not, as before stated, from visual observations of the 1474 K line. In view of the fact that both the prismatic camera and the slit-spectroscope show that H and K do not occur in the spectrum of the corona, it seems impossible to reject the conclusion that the observation in question must be explained in some other way. It is unfortunate that the visual observations of the 1474 K line, which failed for want of light, were not successful.

Professor Norman Lockyer has published a full report of the results obtained with the prismatic cameras (*Phil. Trans.* vol. 187 (1896) A). The excellent series of photographs taken by Messrs. Fowler and Shackleton have yielded a number of interesting results, of which we may briefly mention a few. There is, firstly, the great difference in the forms of the prominences as seen in the different radiations, those in H and K being most intense and reaching to the highest level. The forms of the prominences photographed in the H and K light do not appear to differ sensibly from those photographed directly with the coronagraph. Neither H nor K, nor any of the hydrogen lines, nor D_3 were seen in the spectrum of the corona. It will be remembered that in the early days of eclipse work many observers reported that they had seen bright hydrogen lines in this spectrum. Professor Schuster in his discussion of the results of the 1886 eclipse came to the conclusion that calcium and hydrogen do not form part of

the normal corona spectrum, and we may now accept this as a well-established fact. With regard to D_3, which, being in a non-actinic region of the spectrum, has been photographed only with the prismatic camera, there is not at present quite the same weight of evidence, but there is no reason to doubt that this radiation also is confined to the chromosphere and prominences.

As regards the true spectrum of the corona, the positions of seven lines in addition to 1474 K were measured. These coincide to a certain extent with the results obtained from slit-spectroscopes, but in view of the apparent variability of the corona spectrum and the extreme faintness of the lines it would seem that we have not yet collected sufficient data for a useful discussion. Professor Lockyer is of opinion that the eclipse work strengthens his view that chemical elements are dissociated at solar temperatures, but the question as to the chemical origin of the lines is reserved for a future paper.

1896 *August* 9.—The preparations made to view this eclipse were for the most part nullified by bad weather. A party consisting of the Astronomer Royal, Professor Turner, and Captain Hills went to the island of Yezo, where also were stationed two Japanese parties under Professors Terao and Hirayama, a French party under M. Deslandres, and two American parties under Professors Schaeberle and Todd respectively. Dr. Common and Professor Norman Lockyer, Dr. Copeland, a party about eighty strong of the members of the British Astronomical Association and their friends, and many other observers too numerous to mention in detail, were located on the shores of the Varanger Fjord, Finmark, Norway. At none of these stations was the eclipse seen. It was seen under perfect weather conditions at Bodö, on the west coast of Norway, where, unfortunately however, there were no fully equipped observers. The various Russian parties, at Orlovski, on the Amur, at Tiumen, in Western Siberia, at Siikavuopio, in Swedish Lapland, and in Novaia Zemlya, were fairly fortunate, and obtained several photographs. A small party of English observers, consisting of Mr. Stone and Mr. Shackleton, were kindly taken by Sir G. Baden-Powell in his yacht to Nova Zembla, and, being favoured with exceptionally fine weather, an excellent series of photographs was procured. The discussion of these results has not yet been published, and we must defer a full notice of them till next year.

One result obtained is, however, so important that it deserves mention, and that is the photographing by Mr. Shackleton of the "flash" spectrum at the beginning of totality. Attempts have before been made to secure a record of this phenomenon with the prismatic camera, but have not hitherto been successful. On this occasion, however, the long-desired photograph was secured, and we are now in possession of a record of the much-disputed "reversing layer." Prof. Young has expressed the opinion, based on an examination of the photograph, that the spectrum photographed by Mr. Shackleton is practically line for line identical

with the Fraunhofer spectrum as taken with the same instrument, with the addition of a slit and collimator, and thus the observation, first made by him visually in 1870, is now confirmed.

1898 *January* 21.—The preparations for this eclipse are already in progress, and the Joint Permanent Eclipse Committee hope to send out to India at least seven observers, who will occupy several stations along the line of totality. It seems that the chances in favour of fine weather are considerable, so that it is not likely that the unfortunate experiences of last year will be repeated. E. H. H.

Dr. Gill's Heliometer Observations.

From the Report of the Royal Observatory, Cape of Good Hope, it will be seen that the printing of the great work of Dr. Gill with the heliometer is well advanced. An early copy of volume ii. was presented to the Society in November, but it seems advisable to defer any notice of this very important work until next year, when it will be more completely published.

Mercury and Venus.

Observations made at the Lowell Observatory tend to confirm Schiaparelli's discovery of the equality of the periods of revolution round the Sun and rotation upon their axes for these planets. (See *Monthly Notices*, vol. lvii. p. 148.)

Lunar Theory.

During the past year a treatise on the Lunar Theory has been published by Prof. E. W. Brown, of Haverford College, U.S.A. The general aim of the work is to show clearly the correspondence between the theories of Laplace, de Pontécoulant, Hansen, Delaunay, and the new method with rectangular coordinates; and the author has therefore given special attention to the relations which exist between the various forms of expression for the same function, and to the significations of the constants which arise in integrating the equations for disturbed motion. He has endeavoured, with considerable success, to simplify the methods of the above-mentioned writers, particularly those of Hansen. The treatise is professedly a text-book, but it contains much valuable work.

The Past Opposition of Mars.

The maximum apparent diameter of *Mars* at the late opposition was only about 17″, and during the most favourable period the planet's axis was nearly at right angles with respect to the Earth, so that the regions around both poles were un-

favourably placed for observation. The northern hemisphere generally, however, was better situated than it had been during the two previous apparitions. It is too early at present to give any complete account of recent observations of the surface marking of *Mars*, as opposition only occurred on December 11, but sufficient details have already come to hand to show that valuable results have been obtained, although few very startling changes seem to have occurred. Unfortunately the weather has been abnormally bad over England, even worse than it was in 1894.

The south polar snow cap seems again to have entirely disappeared, as in 1894, though this is not quite certain, on account of the polar regions having been unfavourably situated. The north polar cap re-appeared with all its characteristic brilliancy and whiteness as early as August 21, only thirty-eight days after the winter solstice of *Mars's* northern hemisphere. The observations show that the cap was irregular at this time, extending farther south at some places than at others.

Observations of irregularities at the terminator seem to have been rare during the past opposition, though a good instance of a bright projection was seen at the Lick Observatory on August 28, on or very near Chersonesus. Although no great instance of obscuration by cloud or fog like that of 1894 October occurred in 1896, yet some apparent changes recorded would seem to be due to the presence of cloud. In particular a whitish zone seen for several weeks at Juvisy surrounding the north polar cap, but not so brilliant as the true snow cap, has been ascribed due to this cause.

The system of dark streaks known generally as "canals" naturally constitutes at present one of the most interesting features in connection with *Mars*. This system, as laid down by Professor Schiaparelli, has received still further confirmation from recent observations. A considerable number of the canals discovered in 1894 at Mr. Lowell's observatory have also been confirmed, and many additional ones detected by various observers. Herr Brenner, at the Manora Observatory in particular, reports having seen as many as thirty-one canals not before recorded. This is no doubt due in great measure to the better position of the northern hemisphere for observation. But the network of canals has now attained to such complexity that it is no easy matter to be sure if a new canal has been seen before or not. This difficulty is increased by the fact that comparatively few of the original observations of the past three or four oppositions have yet been published, and, moreover, different observers seldom draw the existing canals exactly the same. An important feature of the recent observations is the further confirmation of the fact that certain canals vary enormously in appearance from time to time. As instances of this the Nepenthes and the canal named Ulysses by Mr. Lowell may be mentioned. The latter was as prominent as the Araxes, according to Professor Cerulli,

although in 1894 the Araxes had been *immensely* superior to the Ulysses. Nepenthes, on the other hand, seems to have been quite feeble lately according to observations by Messrs. Antoniadi and C. Roberts, although in 1894 it had appeared almost black and nearly as plain as the Cassini division of *Saturn's* ring when well open. Moreover, according to observations by Messrs. Antoniadi and Cerulli and at Mr. Lowell's observatory, the Kaiser Sea has recently actually encroached upon the continent nearly so far as Lake Mœris, so as to obliterate part of Libya.

Canals have been seen double during the past opposition by quite a number of observers. The double canals have, in fact, been more numerous than in either of the two previous apparitions, though not in such quantity as to necessarily support the theory that the gemination of the canals is essentially a seasonal change. The fact that the continental regions of *Mars*, to which the canals are chiefly confined, were better situated for observation, would account for a larger number being seen double. An important point in connection with the duplication of the canals is the liability of some of the small dark spots, or lakes, to become double likewise. A notable instance occurred recently in the case of the well-known spot, Trivium Charontis, which was seen double by Mr. H. F. Griffiths at Streatham on November 6, and independently as two circular black spots on November 10 by M. Antoniadi at Juvisy.

A great many delicate details have been seen and drawn by several observers in the large dark areas usually known as "seas," amongst them some narrow dark streaks having a close resemblance to the canals of the continental regions, and several narrow bright streaks, analogous to the well-known Atlantis of Professor Schiaparelli's map—shown in part in Mr. Green's map as Noble Cape.

A. S. W.

Jupiter.

The appearance of the disk was found to be considerably altered when the planet became suitably placed for observation in the autumn of 1895. The "Red Spot" was faint, especially towards its central parts, which appeared almost as white as the south temperate belt. The most conspicuous markings were the two dark spots in the north tropical zone to which the names of the 'violin' and the 'garnet' spots have been given. These were, at first appearance, so dark and so sharply defined that they were mistaken by several observers for the shadows of satellites, but by the end of April they had both become exceedingly faint and difficult to measure. The period of rotation of the second of these has been determined by M. José Comas Sola as $9^h\ 55^m\ 33^s{\cdot}6$, while Professor Rambaut deduces a period of $9^h\ 55^m\ 33^s{\cdot}36$ for the same object. The longitude of this spot is given by Mr. Marth as expressed by the formula, $270°{\cdot}50 - 0°{\cdot}20\ (t - 1896\ \text{January}\ 21{\cdot}0)$.

From measures of photographs taken at the Lick Observatory Mr. A. Stanley Williams has deduced a period of $9^h\ 55^m\ 38^s{\cdot}9$ for spots lying between 40° and 85° north latitude. In a paper in the *Monthly Notices* for January he has also discussed most of the satisfactory determinations of the rotation period made up to that date, and points out that there are nine distinctly marked currents in the planet's atmosphere, which circulate in a due east and west direction, and show little or no movement towards or from the poles.

Dr. Belopolsky finds (*Ast. Nach.* No. 3326) that the equatorial velocity of the planet as determined by spectroscopic observations does not agree exactly with the value of this quantity deduced from the rotation of spots. His spectroscopic observations lead to a velocity of 11·4 kilometres per second in the line of sight, while the value deduced from the motion of spots is 12·1 or 12·8 kilometres per second according to the value assumed for the diameter. This discrepancy, he suggests, may be due to the refraction of light in the planet's atmosphere; but Deslandres' results, viz. V = 12·5, 11·9, 12·1, 11·7 do not support this conclusion. The result communicated to the British Association by Prof. J. E. Keeler is also at variance with Belopolsky's suggestion. From measurements made on four photographs, he finds $V = 12{\cdot}94 \pm 0{\cdot}27$, and points out that the velocity deduced from observations of this sort must be too small if the slit of the spectroscope does not exactly coincide with the equator of the planet.

The dimensions of the planet have engaged the attention of Messrs. Dyson and Lewis, at Greenwich Observatory, of Professor Schur, at Göttingen, and of Mr. Gledhill, at Bermerside, Halifax. Messrs. Dyson and Lewis have employed, in their investigation, both the filar and the double image micrometer, of which the filar micrometer seems to give the more consistent values, while those of the double image micrometer agree more closely with the heliometer results, the difference between the two amounting to about 1″ in each diameter. At the conclusion of his paper Professor Schur gives the following table containing the measures of *Jupiter's* diameters made in the neighbourhood of opposition with the larger heliometers:—

	A	B	$\frac{A-B}{A}$	Weight.
Bessel	37″·66	35″·24	1 : 15·6	2
Johnson	37·31	35·11	16·9	1
Winnecke	37·39	35·20	17·1	2
Main	37·14	34·94	16·9	1
Bellamy	37·19	35·02	17·1	1
Schur	37·42	35·10	16·2	2
Means ...	37·40	35·13	16·52	

In the *Bulletin Astronomique* for February will be found a continuation of Damoiseau's "Tables Écliptiques des Satellites de Jupiter," by Mons. L. Pottier. Damoiseau's tables stop at 1880 and have been continued by Adams to 1890, and by D. P. Todd up to 1900. In Mons. Pottier's paper Tables I. and III. are brought up from 1900 to 1920.

As is well known, Damoiseau's formulæ for the values of the arguments are not quite correctly derived from the fundamental data given on p. iii of his introduction. Corrections have accordingly been applied by Adams (Appendix to the *Nautical Almanac* 1881) to the arguments to make them consistent with the data and with each other. In the *Monthly Notices*, vol. lii. No. 8, Dr. Downing has published the corrected arguments. Mons. Schulhof has also calculated the correct values, but in his tables he prefers to use Damoiseau's values so that the calculation of eclipses before and after 1880 might be exactly comparable. Mons. Pottier has followed the same course in employing Damoiseau's slightly erroneous values, but he adds a table of the corrections which ought to be applied to the arguments according to Dr. Downing, and the greatest difference that these corrections could produce in the computed time of an eclipse for each of the four greater satellites.

The fifth satellite seems to have eluded observation; at least no account of such observations have come under our notice during the year. Towards the end of 1895 Professor Barnard secured some observations with difficulty. On 1895 December 3 the elongation was measured by him as $59''{\cdot}5$, which agrees well with Mr. Marth's ephemeris. The time of elongation was, however, $1^{m}{\cdot}6$ late by the ephemeris, which seems to show that the period adopted is slightly in error. It is still sufficiently precise, however, to enable the satellite to be found for several years.

A. A. R.

Tisserand's Mécanique Céleste, Vol. IV.

The last volume of this treatise was published during 1896, shortly before the sad and sudden death of its author. The first volume appeared in 1888, and was noticed in the Council Report for 1889 by the late Professor Adams, who commended it as "an elegant volume, forming the first part of an extensive treatise on the Mécanique Céleste. This valuable work is founded on the lectures which the author has given at the Sorbonne since 1883, first as the deputy, and afterwards as the successor of Mons. Puiseux. . . . As might be expected, the greatest attention to elegance is shown throughout in the exhibition of the mathematical formulæ, and the attractiveness of the work is much enhanced by the beauty of its typographical execution." These features have characterised the subsequent volumes, which appeared in 1890, 1893, and 1896.

It was the author's intention originally to complete the work in three volumes: the first dealing with planetary theory; the second with the figures and rotations of the heavenly bodies; and the third with the motions of satellites, including lunar theory and miscellaneous matters. But on approaching the last part of his work, he soon found that lunar theory would require a volume to itself, and vol. iii. was accordingly devoted to it. The present volume thus deals with the motions of satellites other than that of our Earth, comets, and miscellaneous matters. The first five chapters are occupied with *Jupiter's* satellites (excluding the fifth, which must be treated separately), in which the author follows Laplace and Souillart. In concluding a brief historical review of work on this problem, M. Tisserand modestly "thinks he may have succeeded in rendering more accessible one of the most beautiful theories of the Mécanique Céleste, which is essentially very simple, and only appears complicated because of a multiple notation which it is impossible to avoid." His labours will be amply repaid if they induce more people to read and work at the subject. It is, moreover, "much to be desired that a complete discussion of the observations should be made anew, as well as the determination of all the constants, including the velocity of light."

Chapters VI. to VIII. are devoted to *Saturn's* satellites. *Iapetus* is first considered, following earlier papers of M. Tisserand himself, and Dr. H. Struve's discussion of the observations. Next follows Professor Newcomb's work on the motion of *Hyperion*, with comments, and again a reference to Dr. H. Struve for a discussion of the observations; and finally an account is given of the beautiful discoveries of the last-named astronomer regarding the intimate connections of the motions of *Mimas* and *Tethys*, and again of *Enceladus* and *Dione*. There is very little to be said of the satellites of *Neptune*, *Mars*, and *Uranus*, which are dealt with in a single chapter. Indeed all the work on satellites only occupies 150 pages out of the whole 550. The remainder of the work treats of the perturbations of comets and their forms, and of the investigations of various kinds connected with minor planets, including brief notices of the work of Gyldén and Poincaré.

Double Stars.

As in the Report of last year, the work in this branch is treated of under two heads—observation and calculation.

Observation.—The measures published during the year 1896 are :—

Monthly Notices, Royal Astronomical Society, 1896 March.

(*a*) Of 19 southern doubles made with an 8-inch refractor by

Mr. John Tebbutt at Windsor, New South Wales, in 1895.

(*b*) Of 142 doubles made with the 28-inch refractor at the Royal Observatory, Greenwich, in the years 1894–5.

Astronomical Journal, 363.—Of 70 *Ophiuchi* in 1894 and 1895, by Schur, at Göttingen.

Ibid. 384.—Of 70 *Ophiuchi* in 1896, by See, at Lowell.

Ibid. 388.—Of 70 *Ophiuchi* in 1896, with 28-inch, at Greenwich.

Ibid. 389.—Of 70 *Ophiuchi* in 1896, by Leavenworth.

Ibid. 382.—Of 58 double stars in 1893, by Leavenworth, at Northfield.

Ibid. 391.—Of 85 *Pegasi* (β 733), by Schaeberle.

Astronomische Nachrichten, 3335.—Measures of double stars by the method of Interference, by Karl Schwarzschild, who places a disc with several parallel slits in front of the objective, as suggested by Michelsen.

Ibid. 3369—Measures of 7 new and 55 old pairs made in 1895, by Mr. Sellors, at Sydney.

Ibid. 3378.—Measures by Dr. Doberck, at Hong Kong.

Astronomical Society of the Pacific.—Mr. Aitken's measures with the 12- and 36-inch telescopes at Lick in 1896.

Annales de l'observatoire de Paris.—Vol. xxi. contains the measures made by M. Bigourdan.

Journal of the B.A.A. vol. vi. No. 8.—A good set of 73 southern stars, made with a 5-inch at Shanghai by Mr. J. L. Scott in 1895.

The Observatory, 1897 January, and *Astronomical Journal*, 385 and 386.—On August 31 Dr. See announced that he had measured the companion of *Sirius* on its reappearance, but that the measures did not agree with the predicted place. Professor Schaeberle and Mr. Aitken afterwards measured an object which they took for the companion. These measures agreed with the ephemeris, and they were unable to see the object measured by Dr. See.

The places given

1896·678	220°·6	5″·07	See (24-inch)
1896·819	189·6	3·65	Schaeberle (36-inch)

Telegrams from Lick also announced that Professor Schaeberle had rediscovered the companion to *Procyon*, not seen since O. Struve's observations in 1873–4. He gives the place as position 318°, and distance 4″·6.

Calculation.—The orbits published during the year are given

below, with the periods, semi-major axes and eccentricities, and also a reference to the publication in which they appeared.

Star's Name.	Period (Years).	a	e	Reference.
β 733, 85 Pegasi	24·0	0·89	0·39	*A.N.* 3339
Σ 1728, 42 Comæ Ber.	25·6	0·64	0·46	*M.N.* 1896 June
β 416, Lac. 7215	33·0	1·22	0·51	*A.J.* 372
Σ 1937, η Cor. Bor.	41·5	0·89	0·28	*A.N.* 3370 (Doberck)
„ „	41·6	0·92	0·27	*A.N.* 3361
A.G.C. 1, Sirius	51·1	7·77	0·61	*A.N.* 3336
„ „	52·2	8·03	0·62	Stellar Systems (See)
OΣ 298	52·0	0·80	0·58	„ „
OΣ 38, γ^2 Andromedæ	54·0	0·37	0·86	*A.J.* 378
A.C. 15, 99 Herculis	54·5	1·01	0·78	*A.J.* 366
Σ 1196, ζ Cancri A.B.	60·0	0·86	0·34	*A.J.* 378
OΣ 234	63·5	0·34	0·36	Stellar Systems (See)
Σ 1967, γ Cor. Bor.	73·0	0·74	0·48	*A.J.* 376
α Centauri	75·6	18·17	0·52	*A.N.* 3330
„	81·1	17·70	0·53	Stellar Systems (See)
OΣ 235	80·0	0·87	0·32	„ „
Σ 2272, 70 Ophiuchi	87·7	4·55	0·50	*A.J.* 363
γ Centauri	88·0	1·02	0·80	*A.N.* 3339
OΣ 208, ϕ Ursæ Maj.	97·0	0·34	0·44	Stellar Systems (See)
Σ 1998, ξ Scorpii A.B.	104·0	1·36	0·13	„ „
Σ 1888, ξ Boötis	128·0	5·56	0·72	*A.N.* 3334
Σ 2729, 4 Aquarii	129·0	0·73	0·51	Stellar Systems (See)
Σ 518, 40 o^2 Eridani	167·0	4·16	0·07	*A.N.* 3366
„ „	176·2	5·22	0·22	*A.N.* 3306
Σ 1768, 25 Can. Ven.	184·0	1·13	0·75	Stellar Systems (See)
Σ 1760, γ Virginis	184·5	3·72	0·89	*A.N.* 3364
Σ 2032, σ Cor. Bor.	370·0	3·82	0·54	*A.N.* 3339

A.N. = *Astronomische Nachrichten.* *A.J.* = *Astronomical Journal.*
M.N. = *Monthly Notices*, R.A.S. Stellar Systems (see below).

Beyond the actual calculation of orbits, the work done includes :—

Monthly Notices, 1896 June.—A paper by Miss Everett, entitled "Galactic Longitudes and Latitudes of Poles of Binary-Star Orbits," in which is a most useful list of double-star orbits, with the positions of their poles. No decided tendency to favour any special region of the sphere is shown.

Astronomische Nachrichten, 3336.—H. F. Zwiers gives a new method of computing a double-star orbit, and applies it to calculate the orbit of *Sirius*.

Popular Astronomy.—Professor Burnham, in a paper on "The Binary Systems," analyses his catalogue of double stars (which to N.P.D. 120° contains 10,940 pairs), and divides them into groups of binaries with good orbits, with doubtful orbits, certain binaries, probable binaries, rectilinear, &c.

In the same publication he discusses the orbits of *Castor* and *τ Ophiuchi*, showing that we must not put too much faith in the calculated orbits.

Astronomical Journal, 378.—Dr See gives a complete list of the 40 orbits computed by him.

The Observatory, *No.* 242.—Dr. Doberck gives a method for correcting double-star measures for refraction.

Ibid. 237.—Mr. Lewis has a note on Σ 305.

Ibid. 238.—Mr. Lewis draws attention to Σ 1074 and Σ 1500.

Researches on the Evolution of the Stellar Systems, vol. i., by T. J. See.—In this volume, which he has published with commendable promptitude, Dr. See has collected his many papers on double stars to form what we may call the body of the work, which he has prefaced by a history of double-star astronomy, and a general review of methods of determining orbits, with an exposition of Kowalsky's method. A final chapter is devoted to preliminary deductions from this mass of material, chief of which are: (1) Double-star orbits have high eccentricities, and on the average twelve times those found in the planetary system, and this extraordinary result is evidently the expression of a fundamental law of nature. (2) The stars of a system are comparable, and frequently almost equal, in mass.

The volume is evidently intended to set forth the materials on which a future research, on the lines of tidal friction as indicated by Darwin, is to be based; but apart from this, it will always serve as a useful reference-book for observers.

T. L.

Chandler's Third Catalogue of Variable Stars.

Mr. Chandler published his First Catalogue in 1888 (*Ast. Journ.* Nos. 179–180), it being then thirteen years since the appearance of Schönfeld's Second Catalogue of Variable Stars, and the need of a catalogue representing the knowledge of the time being thus urgent. In 1893 Mr. Chandler published his Second Catalogue (*Ast. Journ.* No. 300), in which the first was corrected and revised to date, and definitive elements of every star (in the sense that all available observations to date were

used in the calculation) were given. In the introduction to the Third Catalogue, published in 1896 (*Ast. Journ.* No. 379) we read: "Since the appearance of the Second Catalogue, it has been the endeavour to keep pace with the rapid accumulation of new material by the occasional issue of supplements. The time appears now to have arrived when a new edition of the Catalogue is necessary, incorporating everything up to date. . . . The construction of the present Catalogue is in every respect similar to that of the Second Catalogue."

Mr. Chandler remarks with satisfaction on the fact that very few stars in the northern hemisphere have been neglected during the last few years, although there has been no organised attempt at cooperation. "In the southern hemisphere particularly the need for volunteers is pressing."

Dr. Auwers' Zone Catalogue.

In portioning out different parts of the heavens to different observatories for the formation of its well-known catalogue the Astronomische Gesellschaft allotted to Berlin Observatory the zone lying between 14° 50′ and 25° 10′ north declination. This zone was again divided by Dr. Foerster into two, of which the northern half was assigned to Dr. Becker, and the southern to Dr. Auwers. Then Dr. Auwers, with the assistance of Dr. Romberg to read the circle, working with the old transit circle of the Berlin Observatory (4 inches aperture and 3 feet circle, divided to every 2′ of arc), between 1869 February and 1871 August made 22,028 observations of 9,789 stars, exclusive of 2,822 observations of fundamental stars, and this part of the work was finished. Thus it took 2½ years to make the observations, but the reduction and publication of the results have taken nearly 25 years. In order to accelerate the rate of observation, only one microscope was read, and a correction applied to reduce the reading to the mean of the four microscopes usually read. The equator point was determined by three successive approximations, and the final reductions were made to the epoch 1875. A number of systematic corrections have been applied to the observations, but the general results seem satisfactory. The method adopted in reducing the right ascensions was similar to that adopted for the declinations, with the addition of the following novel correction for personality depending on the star's magnitude :—

Mag.	Corr. s	Mag.	Corr. s	Mag.	Corr. s
8·8	·000	9·1	−·031	9·4	−·073
8·9	−·009	9·2	−·044	9·5	−·089
9·0	−·020	9·3	−·058	9·6	−·106

As part of the programme laid down by the Astronomische Gesellschaft, a comparison with older catalogues and a determination of proper motions were included in the scheme. Needless to say, Dr. Auwers has exhausted all available material for the zones under his charge in such discussions, and deduced systematic corrections to the whole of the catalogues involved, entailing a prodigious amount of work. For 1,300 stars in the zone Dr. Auwers has found proper motions, some of which may be open to question. Among them are some of Bradley's stars, the proper motions of which Dr. Auwers had previously determined, but the corrections are usually under $^{s}\cdot001$ and $''\cdot001$ in R.A. and Dec. respectively. In addition to these data, interesting discussions and tables are appended, dealing with the number and distribution of the stars with different proper motions, and an analysis of their average relation to magnitude. The amount of work and figures involved in this book must have been enormous, and the value to be attached to the results can best be gauged by the fact that the responsibility rests on the shoulders of Dr. Auwers, supported by Dr. Romberg, Dr. Battermann, Professor Küstner, Dr. Lamp, Dr. Harting, and Dr. Stumpe.

W. G. T.

A Photometric Catalogue of the Southern Stars.

Though we have become accustomed to see large masses of work produced in a comparatively short space of time by Professor E. C. Pickering and those associated with him in his labour, it is impossible to under-estimate, through familiarity with his methods, the amount of photometric work which Professor S. I. Bailey accomplished during his residence in South America in 1889–91. A scheme which proposed the photometric determination of the magnitude of 7,922 stars, involving as it did some 19,000 measures, would be considered an enormous undertaking if it were not dwarfed to some extent by the amount of photometric work which Professor Pickering has already published. But in contrasting the work of the Southern Observatory with that of Harvard, it would be very unfair to Professor Bailey not to take into account the different circumstances and surroundings under which the work has been accomplished. Professor Bailey was far from the conveniences and support of scientific life. Every difficulty, as it arose, had to be met and overcome by his resourceful energy and ingenuity. He had to rely on his own judgment, knowing that all material assistance was thousands of miles distant. That he succeeded in carrying his instruments to three separate stations without any injury to his equipment, often on the backs of mules and along roads which he himself improvised, tells as much for his care and foresight as the amount of work which he accomplished speaks of his energy and perseverance.

The object of the expedition was to extend to the southern hemi-

sphere the photometric investigations undertaken at Cambridge, and consequently to secure on a uniform plan the magnitudes of all the brighter stars in the sky. With this view the larger of the two meridian photometers that had been in use at Harvard was sent to South America under the charge of Professor Bailey, who had familiarised himself with the use of the instrument in its original position. With this instrument it was proposed that he should measure the brightness of all stars in the following catalogues :—

1. All stars in the *Uranometria Argentina* whose magnitude is given as 6·2 or brighter.
2. All stars in the catalogue of Behrmann's *Atlas des südlichen gestirnten Himmels* described as brighter than the 6th magnitude.
3. All stars in Houzeau's *Uranométrie Générale* except those whose magnitude is given as 6 or 6·7.
4. All stars of the Harvard Photometry south of $-30°$ declination.

This part of the programme is practically an extension of the Harvard Photometry given in vol. xiv. of the *Annals*. To this list were added all those stars from the *Argentine General Catalogue* which lie in a series of zones, twenty minutes wide, whose mean declinations for 1875·0 were $-25°, -30°, -35°$, . . . up to 80°, while all stars in a zone of twice the width were to be included whose magnitudes exceeded the eighth. Certain other stars possessing unusual interest were also added, making a total of 7,922 stars.

Professor Bailey first selected a station near Chosica, in south latitude 11° 52′, and at an elevation of 6,600 feet. Here a small observatory was erected, wherein was located the Bache Telescope for photographic work, in addition to the photometer ; and the work was steadily pursued under a sky which permitted an almost uninterrupted view of the stars. The number of stars observed in a single night more frequently exceeded than fell short of a hundred, and on one occasion no less than 292 stars were observed in 398 minutes. When the rainy season came on, and this excessive activity was no longer possible, Professor Bailey sought for a more congenial site in a lower latitude. Here, at Pampa Central (lat. $-23°$ 10′), he accomplished the record feat of observing no less than 302 stars on a single night, and the condition of the station is shown generally by the fact that observations were possible on 33 nights out of the 43 during which he remained there. From this station Professor Bailey returned to Chosica, where the third section of the work was carried on, and finally removed to Arequipa, which town had been selected by Professor Pickering as the position for the permanent establishment of a branch observatory. In 1891 May Professor Bailey, having finished the task with which he had been entrusted, handed over the charge of the observatory to

Professor W. H. Pickering, and he himself returned to Harvard, taking the meridian photometer with him.

It is perhaps far too early to speak of the degree of accuracy that the observations made under such unusual circumstances possess. The agreement of the results between themselves is in this instance a particularly untrustworthy criterion. The circumstances under which the photometer was used differ considerably from those that obtained at Harvard, where a thorough and unflinching criticism has been applied to the observations. At Chosica, as at Harvard, the image of the star whose magnitude was sought has been compared with that of a polar star. But while at Harvard the polar star had a zenith-distance never greater than about 49°, at Chosica the comparison star would have a zenith-distance of about 78°, and at the most southern station would not be more than about 28° above the horizon. Under these conditions the effects of atmospheric absorption are very different from those at Cambridge. The effect is not so important on an individual star as on the standard star with which a whole night's work is compared. The derivation of the correction on account of atmospheric absorption demands such an increase of observation that one might well doubt whether the meridian photometer is the best adapted for the work to which it was applied. Professor Pickering, aware of the difficulties, arranged his plan of observations accordingly, and has applied methods of reduction which are apparently successful; but for a full description reference must be made to the volume itself. There are, however, anomalous circumstances which seem to imply either that the nights devoted to photometric work were not always suitable, or that the processes of reduction still leave something to be desired. For instance, there are several nights in which the computed value of the atmospheric absorption is *negative*. This would imply that a star near the horizon appeared brighter than when at the zenith, and on some occasions by no inconsiderable quantity. Such results have not been rejected as impossible, but have generally been retained, though it is a question if the final accuracy is increased by the incorporation of such observations.

The magnitudes of the brighter stars have been formed into a catalogue (containing 1,428 stars) with approximate coordinates for 1900, and reference numbers to other well-known catalogues, such as Stone, the Argentine Uranometry, etc. Also the magnitudes estimated by Houzeau and others have been inserted for comparison. This is the practical extension of the Harvard Photometry to the whole sky, and is probably the most accurate part of the work, as the observations are usually more numerous and the chance errors consequently better distributed. Also the instrument, with its aperture of 10·5 cm., is better adapted to measure the light of the stars which enter into this catalogue than of others, verging on the tenth magnitude and even feebler, which appear in other parts of the work.

W. E. P.

The Cape Photographic Durchmusterung.

In 1885 Dr. Gill commenced a photographic survey of the heavens from Decl. −18° to the S. Pole. He secured the cooperation of Dr. Kapteyn, who undertook the measurement and reduction of the photographic plates. The first instalment, which has just appeared, extends from Decl. −18° to −37°, and contains over 150,000 stars. The photographs are taken with a rapid rectilinear Dallmeyer lens of 6 inches aperture and 54 inches focal length. Each plate covers 6° by 6° of the sky, and the centres of the plates are about 5° apart on parallels of declination 5° distant. They are taken in duplicate to eliminate the risk of setting down accidental specks as stars.

The exposures are regulated by the condition that a photograph of any selected region should show all the stars given by Argelander, and vary from one hour to thirty minutes, according to the quality of the nights and sensitiveness of the plates employed.

The machine with which the plates are measured, designed by Dr. Kapteyn, gives the right ascensions and declinations directly. All measures are made in duplicate, the discordances, omissions, &c. being examined by Dr. Kapteyn himself. The right ascensions and declinations are reduced to the epoch 1875·0; their probable error is given as $\pm 0^{s}\cdot 27$ and $\pm 2''\cdot 6$ respectively. Great attention is given to the identification of the stars, and references are given as far as practicable—it being inconvenient to print more than five for one star—to the catalogues in which the stars occur, along with their visual magnitudes. Lists are also given of the brighter stars which occur in various southern catalogues, and are not found on the photographic plates.

The magnitudes are obtained by comparison with the stars on the plates whose visual magnitudes are given in Schönfeld's *Durchmusterung* or Gould's *Zone Catalogue*, thus making the mean photographic magnitude correspond with the mean visual magnitude. The formula employed connecting the magnitude with the diameter is, magnitude $= \frac{B}{\text{diameter}+C}$. The average number of stars per square degree is 25·4, and varies from 6 to over 100, according to proximity to the Milky Way. In the *Bonn Durchmusterung* the number of stars is 15·2 per square degree, and in Schönfeld's *Durchmusterung* is 18·5. It is of interest to compare the *Cape Durchmusterung* with Dr. Thome's *Cordoba Durchmusterung*, of which an account was given in the Report of the Council in 1894 February, as these were made almost simultaneously, one by photographic methods, and the other visually.

	Decl.	No. of Stars.	No. per Sq. Degree.	Probable Errors.
Cordoba	-22° to -42°	340,000	56·1	$\pm 0^{s}\cdot 42$ in R.A. $\pm 13''\cdot 8$ in Decl.
Cape	−18 „ −37	152,000	25·4	$\pm 0^{s}\cdot 27$ „ $\pm 2''\cdot 6$ „

The scale of magnitudes in these two surveys is compared by Dr. Kapteyn, who also discusses the variations between visual and photographic methods depending on the distance from the Milky Way.

P. W. D.

The Astrographic Chart.

The fourth *réunion* of the Comité Permanent was held in Paris in May. The reports furnished by the directors of the co-operating observatories show that satisfactory progress has been made in two-thirds of them. Owing to political or financial difficulties, the work has not yet begun at Santiago de Chili, La Plata, and Rio Janeiro, and is seriously hampered at several other observatories.

The following table shows how far the photo-mapping has advanced in the different zones:—

	Zone.	No. of Fields Assigned.	No. taken for Cat.	No. taken for Chart.	
Greenwich	+90 to +65	1,149	728	472	213 plates measured; 102 plate constants determined
Rome	+64 „ +55	1,040	280	100	—
Catania	+54 „ +47	1,008	21	None	—
Helsingfors	+46 „ +40	1,008	1,008	A few	160 plates measured and partly reduced
Potsdam	+39 „ +32	1,232	500	„	35,000 stars measured
Oxford	+31 „ +25	1,180	800	None	40,000 stars measured on 160 plates
Paris	+24 „ +18	1,260	1,155	Not stated	318 plates measured, 60 reduced
Bordeaux	+17 „ +11	1,260	300	60	Measures to be begun soon
Toulouse	+10 „ + 5	1,080	150	350	70 plates measured
Algiers	+ 4 „ − 2	1,260	1,000	64	168 plates measured with 32,000 stars
San Fernando	− 3 „ − 9	1,260	1,260	about 400	50 plates measured once and 25 twice
Tacubaya	−10 „ −16	1,260	529	Not stated	Measuring to begin soon
Santiago de Chili	−17 „ −23	1,260	—	—	—
La Plata	−24 „ −31	1,360	—	—	—
Rio Janeiro	−32 „ −40	1,376	—	—	—
Cape of Good Hope	−41 „ −51	1,512	1,512	Nearly half	30 plates measured
Sydney	−52 „ −64	1,400	1,393	1,112	—
Melbourne	−65 „ −90	1,149	703	A few	—

Examination of this table shows that (omitting altogether the three South American Observatories which have not yet

commenced) the taking of the catalogue plates is generally well advanced, and that some progress has been made with the chart plates. The measurement and reduction of the catalogue plates has been begun by more than half the observatories, and considerable progress has been made by six or seven of them.

The Congress first turned its attention to the degree of accuracy which it was desirable to obtain in the measurement of the photographs. It was decided that the probable error of the measured coordinates ought not to exceed $\pm 0''.20$.

The choice of the reference-stars and the methods of measurement and reduction were left to the discretion of the directors of the cooperating observatories. It was resolved that the measured rectilinear coordinates should be published as soon as possible, along with the necessary data for obtaining the right ascension and declination of the stars when required. With regard to the magnitudes, the Congress laid down no conditions except that the methods adopted for their determination should be capable of precise definition, so that the scales employed at different observatories might be readily comparable. For the Chart it was decided that in the odd zones a triple exposure of 30^m should be given.

Captain Abney undertook to supply the different observatories with scales which should be printed on the plates at the same time as the *réseau*, and supply a measure of the sensibility of the plates for light of different intensities. It was also resolved that two positives of each chart-plate should be made on glass, and that one of them should be placed in the Bureau National des Poids et Mesures.

Several papers have appeared during the year, exemplifying the methods adopted at various observatories (*e.g.* Paris, Helsingfors, Greenwich) for the determination of plate constants, and the accuracy which may be obtained from the measures on the catalogue plates.

It is our sad duty to record the death of the President of the Comité Permanent, M. Tisserand, the distinguished Director of the Paris Observatory.

F. W. D.

The International Conference on Fundamental Stars.

It has long been recognised as a desideratum in practical astronomy that the adopted places of stars as given in the astronomical ephemerides of different nations should be deduced from a uniform system of fundamental places, and from a uniform system of elements of reduction. The advantages of such a step are sufficiently obvious, and, as the time seemed almost ripe for the carrying out of the project, correspondence on the subject took place during the course of the year 1895 between the Directors of the National Ephemerides of America, England, France, and Germany. The matter was warmly taken up

by the *Bureau des Longitudes*, and it is mainly due to the exertions of that learned body that the necessary preliminaries were arranged in such an entirely satisfactory manner. In the event it was decided to hold an International Conference in Paris at the close of the meeting of the Astrographic Congress, which had been fixed for the month of May, 1896. Each of the Directors of the four great National Astronomica Ephemerides mentioned above was authorised to nominate a colleague, who would be invited to attend the Conference; and Dr. Gill was specially invited to attend as representing the observatories in the southern hemisphere. The *personnel* of the Conference was definitely arranged as follows :—

America ...	...	MM. Backlund and Newcomb
England ...	...	Christie and Downing
France ...	...	Loewy and Tisserand
Germany ...	...	Auwers and Bauschinger
S. Hemisphere	...	Gill.

Professor van de Sande Bakhuyzen and M. Trépied attended as consultative members of the Conference, and undertook the secretarial duties.

M. Faye, the learned and venerable president of the *Bureau des Longitudes*, was nominated President of the Conference, and occupied the chair at the opening meeting. On subsequent occasions the chair was taken by M. Loewy, the vice-President of the Conference. MM. Auwers and Christie were unable to attend the meetings of the Conference.

The following resolutions were adopted, after ample discussion and with practical unanimity :—

1. For the general fundamental catalogue the equinox should be determined solely from the observations of the Sun, excluding those of *Mercury* and *Venus*.

The absolute correction of the right ascensions of the system called N_1 (*i.e.* that of the catalogue of 1,098 equatorial and zodiacal stars published in vol. i. of the *Astronomical Papers of the American Ephemeris*) being very small, it was decided that this correction should be neglected, or, in other words, that the equinox of the system N_1 should be adopted.

2. In view of the uncertainty that still exists with regard to the numerical value of the personal error depending on magnitude, which affects the right ascensions of stars, it was decided that corrections for these errors should not be applied in the ephemerides.

But as the existence of such personal errors cannot be doubted, the Conference considered that the observatories should undertake researches necessary for the determination of their numerical values.

3. On the point as to whether the century should be adopted as the unit of time for the first term of precession, as well as for the secular variation, the Conference left it to those who would be

entrusted with the duty of constructing the fundamental catalogue to select the form of expression that appeared to them to be most convenient.

4. The Conference entrusted to Professor Newcomb the duty of determining the definitive values of the luni-solar and planetary precessions.

Professor Newcomb undertook to finish this work within a year.

5. The Conference recommended the following values of the astronomical constants named :—

Nutation	$9''.21$
Aberration	20·47
Solar parallax	8·80

6. With regard to the reduction of mean to apparent places of stars, it was decided :—

a. That the term of short period in right ascension

$$f' = -0''.1866 \sin 2(\odot + 0''.0622 \sin(\odot - \Gamma'),$$

which has the same value for all stars, should be omitted in the ephemerides for polar as well as for equatorial stars.

b. That all the other terms of short period should be omitted in the ten-day ephemerides, but retained in the cases of polar stars, the apparent places of which are given for every day.

c. That these same terms of short period should be omitted in the ephemerides of the Sun and planets.

7. Professor Newcomb was entrusted with the duty of preparing a provisional fundamental catalogue in accordance with the system adopted by the Conference. All details that had not been definitely settled should be discussed by correspondence. The catalogue should be finished within a year.

The Conference regarded it as a matter of the highest scientific importance that Professor Auwers should continue his researches, so as to complete his definitive fundamental catalogue.

8. The Conference expressed the hope that each star of the common fundamental catalogue should appear at least once in one of the four ephemerides—viz. *American Ephemeris*, *Berliner Jahrbuch*, *Connaissance des Temps*, and *Nautical Almanac*.

9. It was considered desirable that a common catalogue of zodiacal stars should be adopted, and that the positions of the provisional fundamental catalogue should be taken as its basis ; that the distribution of the stars of the zodiacal catalogue should be in accordance with Dr. Gill's proposals ; and that the observation of these stars should be particularly recommended to the observatories.

10. The Conference expressed the hope that a scheme of international co-operation might be established for the calculation of the perturbations and ephemerides of minor planets.

11. The Conference expressed the opinion that a first-class

reversible instrument, suitable for fundamental determinations, should be erected in one of the observatories of the southern hemisphere.

12. The decisions of the Conference, in so far as they refer to changes in the values of astronomical constants, should take effect in the ephemerides for the year 1901.

In order to carry out the decisions of the Conference, Professor Newcomb has been busily engaged since his return home on the construction of the provisional fundamental star catalogue, which will contain the places of about 1,000 stars. The initial epoch of the catalogue is 1875. The *Bureau des Calculs* of the *Connaissance des Temps* and the *Nautical Almanac* Office, aided by the assignment to it by the Admiralty of a sum of money for the purpose, are about to undertake in concert the computation of the reduction-elements necessary for bringing up the catalogue places to 1900. There appears, therefore, every reason to expect that the catalogue will be ready in good time, and that astronomers may look forward to the inauguration of a new era in the history of astronomical ephemerides at the commencement of the twentieth century.

A. M. W. D.

Professor Rowland's Preliminary Table of Solar Spectrum Wavelengths.

Professor H. A. Rowland has continued during the year the publication of his "Preliminary Table of Solar Spectrum Wavelengths," which he commenced in the number of the *Astrophysical Journal* for 1895 January. The Tables published in 1895 carried the spectrum from λ 3722 well in the ultra violet to λ 5914 in the orange. Those published last year completed the visible spectrum down to λ 7331, and have commenced the region of the extreme ultra violet at λ 2976, and brought it down to λ 3260, the calculations of wavelengths in this region not having been completed at the time when publication was first commenced.

This, the fullest catalogue of the solar spectrum yet attempted, contains in the Tables which have so far appeared some sixteen thousand lines. The wavelengths have been determined from measurements made by Mr. L. E. Jewell of Professor Rowland's photographs of the solar spectrum, and are reduced to wavelengths in air at 20° c. and 760 mm. pressure.

The intensities of the lines are given in numbers from 1 to 1,000, it being quite rightly decided that the ordinary scale from 1 to 10 is far too limited in range.

Lines seen with difficulty are indicated by one or more zeros according to the faintness of the line. The wavelengths are expressed in tenth-metres and to the third place of decimals. A

large number of lines are referred to the element producing them, the spectrum of every known element except gallium having been photographed at the Johns Hopkins University in connection with the solar spectrum. The measurement of these plates will, however, occupy several years, so that the identification of the lines will receive much greater extension in the future.

It must, under the most favourable circumstances, be a considerable time before the work is completed, so the author has wisely determined to publish this preliminary table of the solar lines, leaving it to be added to or corrected at a future time until the final list can be compiled.

When we bear in mind the number of spectroscopic theories that have been based on imperfect and erroneous observations, we shall be able readily to appreciate the enormous service that Professor Rowland has rendered, firstly, by the construction of his unrivalled ruling-engine; and secondly, by the excellent use to which he has put the beautiful gratings thus obtained.

The expenses of this great fundamental work have been partly borne by grants from the three following funds:—The Bache fund of the National Academy of Sciences, the Rumford fund of the American Academy of Sciences, and the Bruce fund of Harvard College Observatory.

Spectroscopic Astronomy in 1896.

Oxygen in the Sun.—Professors Runge and Paschen have recently succeeded in resolving a line in the extreme red of the spectrum of oxygen, discovered by Professor Piazzi Smyth. The line appears to consist of three components, apparently coinciding with three lines of the same relative intensity in the solar spectrum. From such evidence as is at present available, these lines do not appear to be due to the influence of our own atmosphere, and therefore may be supposed to have a true solar origin.

Water-vapour in the Atmosphere.—Mr. L. E. Jewell has carried out systematic observations of the region of the "rain-band" for the purpose of ascertaining the value of the spectroscopic method for determining the quantity of water-vapour in the air. Observations were made both by eye and by photographic means, but the latter method was soon discontinued as unsuitable, and reliance placed on the eye-observations alone. Mr. Jewell concludes, in disagreement from the earliest workers on the "rain-band," that observations made with small spectroscopes, or by pointing a spectroscope towards the sky instead of towards the Sun, are of little or no use. Nor is the spectroscope of great value for weather predictions. Its great use is for the study of the distribution of water-vapour in the atmosphere.

Water-vapour in the atmosphere of Mars.—Professor W. W. Campbell has criticised in considerable detail the early observations which appeared to point to the presence of water vapour in the Martian atmosphere, concluding that they were insufficient to demonstrate its presence. Mr. Jewell also urges that the means hitherto used for this purpose have been utterly inadequate, and that nothing could be determined with regard to the presence of water-vapour in the atmosphere of *Mars* unless its amount was much greater than in that of the Earth. The presence of oxygen might possibly be detected by observations made at a considerable elevation.

Two new spectroscopic Binaries.—Two of these interesting objects have been discovered during the year in the examination of the Draper Memorial photographs. The first is μ_1 *Scorpii*, a first type star with the additional lines characteristic of the *Orion* group. The period appears to be $34^h\ 42^m{\cdot}5$, and the orbit to be circular. The second is Lacaille 3105, A. G. C. 10534. The period in this case is nearly the same as of β *Aurigæ*, being $3^d\ 2^h\ 46^m$. The only other spectroscopic binary yet known, ζ *Ursæ Majoris*, has a much longer period, being one of about fifty-two days.

Zeta Puppis.—The spectrum of this star as described by Mrs. Fleming from the Draper Memorial photographs appears unlike any other as yet obtained. The continuous spectrum is traversed by three systems of lines: first, dark lines, of hydrogen with the K line; next, two bright lines, which may be identical with two characteristic lines of stars of the fifth type; and, thirdly, a set of six lines forming a rhythmical series not known in any element with which we are yet acquainted.

Stellar Motions in the Line of Sight.—A number of suggestions have been made recently for enabling the objective prism to be used in the determination of the motion of stars in the line of sight. Hitherto it has been the one great objection to this instrument that it was not available for this research. In 1895 Professor Orbinsky pointed out that the recession of a star involved a contraction in the distance in the interval between two distant lines in the photograph of a stellar spectrum obtained with an objective prism, and he proposed, by photographing two or more spectra side by side, to make the measures differential and not absolute. M. Deslandres proposes an apparatus by which a comparison spectrum might be obtained at the same time as the spectrum of the star. Mr. Maunder has suggested the measurement of the total deviation of a ray by photographing the spectrum of a star, the objective prism being used, and then removing the prism to photograph the star itself on the same plate, reading the angle between the two positions of the telescope by means of an accurate declination circle. Professor E. C. Pickering has worked out another method applicable for determining the relative motions of two or more stars near enough to be photographed upon the

same plate, the distance between the same line in the two spectra being shortened if the violet end of the spectrum of the more rapidly approaching star is directed towards the other spectrum.

Hitherto none of the suggested methods have seemed perfectly suitable, but from the earnest attention which the question is now receiving, it may be hoped that it will not be long before the problem is finally solved.

A New Star in Centaurus.—Circular No. 4 of the Harvard College Observatory announced the discovery of a *Nova* in the constellation *Centaurus*. It was found by Mrs. Fleming on examining some of the Draper memorial photographs, taken at Arequipa. No trace of it could be found on the fifty-five plates taken from 1889 May 21 to 1895 June 14, but its magnitude was 7·2 on plates taken on 1895 July 8 and 10. In December of the same year it had sunk to the 11th mag. It was discovered from the peculiarity of its spectrum, as taken on July 18; its spectrum resembling that of the nebula surrounding 30 *Doradus*, and of the star *A.G.C.* 20937. Its spectrum, as examined visually on December 19, was monochromatic, and closely resembled that of the adjacent nebula *N.G.C.* 5253. Its approximate position for 1875 is *R.A.* $13^h\ 32^m\ 51^s{\cdot}8$, *S. Dec.* 30° 59′·58.

Geodesy.

During the past year H.M. Astronomer at the Cape has published his Report on the Geodetic Survey of South Africa, the work of which was done by Colonel Morris, R.E., C.M.G., Lieutenant Laffan, and a party of Engineers, during the years 1883–92, under the direction of Dr. Gill.

The expense of this survey was borne jointly by the Governments of Cape Colony and Natal. The survey which, thanks to Dr. Gill's persistence, is of the nature of a contribution to scientific geodesy rather than a mere effort in map-making, consists of the measurement of base lines at Natal, Port Elizabeth, and Kimberley, and triangulation which connects these, and with them the base line measured by Sir T. Maclear in Zwartland in 1841, the length then found being adopted without change. The line of triangulation follows the coast line pretty closely from Natal to Port Elizabeth, thence to Cape Town and northward almost as far as Orange River. The Kimberley base line is connected with that at Port Elizabeth by a line of triangulation approximately north and south, and this line is connected with that along the west coast by a line from Hanover to Calvinia. There is a further tie-chain joining this last line with that along the south coast, and the triangulation in Natal is extended northward from the base, which is fourteen miles from Pietermaritzburg, to the northern boundary of the colony and eastward to Durban.

The base lines were measured by means of five 10-foot measuring-bars, which were compared with the Cape 10-foot

standard bar A, previously used by Sir Thomas Maclear. This standard bar, by the courtesy of the Comité Internationale des Poids et Mesures, was compared with the Règle Géodésique No. 2 in charge of that institution, so that the absolute lengths of this survey are comparable with those of European surveys. The Natal base, which is of 10,800 feet, was first measured, and was divided into three sections; the lengths of the two outer sections were derived in terms of the middle by triangulation, and the close agreement between the lengths of these outer sections thus determined with their measured lengths led Dr. Gill to decide that the measurement of long base lines was not an absolute necessity, and therefore for the Port Elizabeth and Kimberley bases lengths of 5,600 and 6,000 feet only were measured, which were extended by triangulation to about 17,058 feet and 14,760 feet respectively.

It would be beyond the scope of this note to follow the work and its reduction in detail. It may suffice to say that in the final tables of results the adjusted angles and lengths of the sides of all the triangles are given, and incorporated with them are the similar quantities found by Maclear in his survey of 1841–1848, which have been adjusted to the system of the present circuit. From these are computed the latitudes and longitudes of all stations, and the azimuths of all lines, the latitude and longitude of Buffelsfontein, and the line Buffelsfontein to Zuurberg being taken as the origin of these. Clarke's elements of the figure of the Earth were used for this computation. Besides the triangulation, as above described, astronomical observations for latitude were made at nineteen stations, of azimuth at twelve stations; and the differences of longitude between eight stations and the Cape Observatory transit-circle were determined telegraphically. These astronomical results are compared with the geodetic (it should be mentioned that the longitude of Buffelsfontein above referred to was deduced from that of the Cape Observatory from the triangulation), and the discussion of this comparison leads to some interesting remarks by Dr. Gill. Dr. Gill is not satisfied that the astronomical longitude results, which were obtained by members of the staff of the Cape Observatory in co-operation with Colonel Morris, are all free from systematic error due to variation of personal equation, and in the case of two best determined arcs, the astronomical and geodetic values differ by about $4\frac{1}{2}^{\mu}$; but by using Airy's elements of the figure of the Earth, instead of Clarke's (a convenient table is computed for making this change) this difference is reduced to about 1″. There are similar differences between the geodetic and astronomically determined latitudes, sometimes as large as 10″, but the substitution of Airy's for Clarke's elements has little effect on these. Dr. Gill thinks that these discordances arise from local attraction, "where the contour of the Earth's surface would lead to the expectation that no deviation of the plumb line would be found," and his experience gained from this work leads him to think that a

desideratum in any survey is the multiplication of stations at which astronomical observations are made.

Dr. Gill, Col. Morris, and all concerned are to be congratulated on the completion of their labours, which is the first contribution to Geodesy in the southern hemisphere, if we except Maclear's somewhat limited survey in verification of Lacaille's meridian arc, and probably the first step in an accurate survey of the whole of the African continent.

Another recently published work on this subject is by General J. T. Walker, R.E., C.B., F.R.S., a former superintendent of the Indian Trigonometrical Survey, whose death occurred in February last. This memoir, entitled *India's Contribution to Geodesy*, appeared in the *Philosophical Transactions* for 1895, and is a history of the Great Indian Trigonometrical Survey and *résumé* of results from its beginning in 1800, to the present time. There are various notes on the instruments used, and tables of their probable errors. Latitudes and longitudes are computed from the results of the triangulation with Col. Everest's elements of the Earth, and also with Col. Clarke's latest determination, which are compared with the astronomically determined latitudes and longitudes. The comparison goes far to show the superiority of Clarke's elements. In the section on astronomical longitudes, there is an instructive account of a certain discordance found in determinations of time, when made in the two positions of reversible transit instruments, which led to large circuit errors in the longitude results. The cause of this discordance was ultimately traced to an imperfection in the method of determining the collimation error. The differences of latitude determined geodetically and by astronomy, and the difference of lengths of geodetic and astronomical longitude arcs, show some remarkable effects of abnormal local attraction. The deviation of the plumb line at Dehra Dûn, for instance, causes a discordance of about two seconds of time in the longitude. Finally, General Walker derives from the accumulated data eight meridional arcs, of amplitude ranging from 2° 24′ to 3° 38′, freed from the effects of local attraction with their corresponding lengths in feet, and four longitude arcs, two of about 24° 49′ amplitude, almost free from local deviation with their corresponding lengths. Of these results, he says in his concluding paragraph: "The eight meridional and the two longest longitudinal arcs here given are believed to be the most valuable contribution to Geodetic science that has yet been made. They are the results of operations which have been carried on in India during a period of over ninety years, with more or less vigour at different times, but always with the cordial support and approval of the Government of India."

H. P. H.

New Observatories.

On 1896 April 7 the new Royal Observatory, Edinburgh, was formally opened by Lord Balfour of Burleigh, Secretary of State for Scotland.

This building on the Blackford Hill replaces the observatory on Calton Hill originally established by a small body of scientific gentlemen of Edinburgh in 1811 with the help of the Edinburgh Town Council, which was taken over by the Crown as a Royal Observatory in 1834. In 1889 the Earl of Crawford presented to the Edinburgh Observatory the astronomical library and the collection of instruments which had formed the equipment of his observatory at Dunecht, and it was decided by the Government that these should be housed in a building on a site better fitted for observation than Calton Hill, where the atmosphere had become unsuitable owing to the growth of the city. The new site was chosen on Blackford Hill; the Town Council made a grant of land, and at the same time relieved the Government of the care of the Calton Hill building, which is to be utilised as a popular observatory; and the Government voted 30,000*l.* for the building. The plans were made by, and carried out under the direction of, Mr. W. W. Robertson, of H.M. Office of Works; and the result is an observatory magnificently adapted for its purpose, which may be described shortly as consisting of two domes, 100 feet apart, with a terrace between. The chief instruments at present are the 15-inch refractor formerly belonging to Lord Crawford, and the 24-inch reflector made by the firm of Grubb for Professor Piazzi-Smyth.

It was expected that the inauguration ceremony of the Yerkes Observatory would have taken place last autumn; but delay in the building prevented this. The observatory is, however, nearly completed. The staff of this institution, which is a branch of the Chicago University, consists of the Director, G. E. Hale, S. W. Burnham, E. E. Barnard, and F. L. O. Wadsworth.

Two other American Universities are said to be adding Practical Astronomy to their scheme of work. The University of Ohio, Columbus, is setting up an observatory with a refracting telescope of 12 inches aperture; and the University of Illinois, Champaign, is also providing a similar building, with a telescope of the same aperture.

An observatory, whose present work is to be the study of variable stars and stellar photometry generally is to be established at Rössgen, Mittweida, Saxony, under the direction of Dr. Friedrich Krueger.

Mr. Percival Lowell has removed his observatory from Flagstaff, Arizona, to a hill about three miles north of the City of Mexico.

H. P. H.

The Adams Memorial.

In the autumn of the past year, 1896, within a few weeks of the fiftieth anniversary of the discovery of *Neptune*, there was published the first volume of the Collected Scientific Papers of the late Professor John Couch Adams.

This volume, to quote the words of the preface, "contains all the original papers which were published by him during his lifetime, extending from 1844 (when he was 25 years of age) to 1890"—in all 62 papers.

A biographical notice is prefixed to the volume (pp. xv.–xlviii.) and has been written by Dr. Glaisher. A great part of it is devoted to a statement of the facts relating to the memorable discovery of *Neptune*. The task has been accomplished with admirable fairness and tact and lucidity. Dr. Glaisher gives so vivid an account of the sequence of events that the reader lives through the time again, sharing the warm feeling of a past generation, forming his own opinion afresh, and justifying the judgment which has been passed by all nations. Two notes of historical interest are reproduced in *facsimile*—Adams' memorandum of his intention of investigating the irregularities in the motion of *Uranus*, and the note which he left at Greenwich in 1845 October, giving the results of the success of his analysis in the search for an exterior planet. Challis's first report to the Cambridge Observatory Syndicate is also printed in full. The portrait of Adams which forms the frontispiece is the engraving by Stodart from the photograph by Mayall.

The papers are arranged not chronologically, but as far as may be according to subject-matter. The papers relating to *Neptune* and *Uranus* naturally come first. Next follow notes about comets, the orbit of γ *Virginis*, the total eclipse of 1851 (which Adams himself went to observe), and papers relating to planetary and lunar tables. The memorable paper, "On the Secular Variation of the Moon's Mean Motion," published in 1853, is followed by other papers on lunar theory, ranging between the date just mentioned and 1888. Next comes the paper on the orbit of the November meteors. As we turn over the pages of the volume we realise anew how much of Adams' work has passed into the history of astronomy.

In the publication of this volume and in the distribution of copies to learned societies at home and abroad, another part of the Adams Memorial has been completed, and we understand that the second volume is so far forward that it is possible to foresee that a sum of about 200*l.* will remain to be offered to the Master and Fellows of St. John's College, Cambridge, to form an exhibition fund for the encouragement of the study of mathematics and physics by the undergraduate students of the college.

Universal Time.

In the Report of the Director of the Natal Observatory, published during the past year, it is stated that the official time of the colony is now that of the thirtieth meridian east of Greenwich, and that the Time Signal is now sent from the observatory at 1 o'clock Natal Uniform Time, which corresponds to $11^h\ 0^m\ 0^s$

Greenwich Civil Time. From articles in colonial newspapers, it appears that there is some feeling that this time system should be adopted for the whole of South Africa. At present the time used in Cape Colony, the Transvaal, and Orange Free State is 1½ hour fast on that of Greenwich.

Since 1895 January 1 Mid-European time (1 hour fast on Greenwich) has been in use in Norway, so that the list of countries where the time is that of the Greenwich meridian, or differs from it by an integral number of hours, is now: Great Britain, Belgium, Holland, Denmark, Norway, Switzerland, Italy, Germany, the colony of Natal, all the Australian colonies, Japan, the United States, and Canada.

It is believed that Mid-European time is also used on the railways of Sweden and in several towns in Austria (Vienna is not one of these); also that in Bulgaria, Roumania, and European Turkey, East European time (2 hours fast on Greenwich) is used; but there is no information that this is the legal time of these countries.

At the latter end of 1896 the suggestion was raised in the French Chamber of Deputies that the time of the Greenwich meridian should be adopted throughout France. The matter was referred to a committee, the majority of whom were in favour of the proposal.

It may be added here, though this does not fall within the scope of the above heading, that on and after May 1 next the standard time of Belgium will be reckoned from 0 to 24 hours, that is, the hour immediately following noon will be numbered 13 instead of 1, as at present.

H. P. H.

Papers read before the Society from March 1896 to January 1897.

1896.

Mar. 13. Note on the indexing of scientific papers. H. Seward.

Description of a spectroscope (the Bruce spectroscope) recently constructed for use in connection with the 25-inch refractor of the Cambridge Observatory. H. F. Newall.

Observations of the variable star R. *Carinæ* from 1890 December to 1895 August. J. Tebbutt.

Discovery and observations of comet *Brooks* (*d.* 1895). W. R. Brooks.

Observations of the variable stars *W*, *X*, and *Y Sagittarii*. Lieutenant-Colonel E. E. Markwick.

Elliptical orbit elements of comet *b* 1894 (Gale). Rev. T. Roseby.

Results of double-star measures with the 8-inch equatorial at Windsor, New South Wales, in 1895. J. Tebbutt.

On the relative efficiency of a reflector and of portrait-lenses for the delineation of celestial objects. Isaac Roberts.

Observations of comets made at the Royal Observatory, Edinburgh.

Note on Mr. Stone's paper "Expressions for the elliptic co-ordinates of a moving point to the seventh order of small quantities." E. W. Brown.

Fireball of 1895 November 22. W. F. Denning.

On the systematic errors of measures on photographic plates. H. H. Turner.

Note on a curious light (the zodiacal light ?) as seen at Oxford, 1896 March 4. H. H. Turner.

Variation of *T Centauri*. A. W. Roberts.

Results of micrometer measures of double stars made with the 28-inch refractor in the years 1894 and 1895, at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

A graphical method of solving Kepler's equation. H. C. Plummer.

Note on the sensibly-cylindrical forms of the pivots of

Mar. 13. the transit-circle of the Radcliffe Observatory, Oxford. E. J. Stone.

Note on the zodiacal light of 1896 March 4. W. H. Robinson.

Note on Professor Turner's paper on the systematic errors of measures of photographic plates. W. H. M. Christie and F. W. Dyson.

Observations of comet *a* 1896 (Perrine-Lamp) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the proper motions of certain fundamental stars. W. G. Thackeray.

Apr. 10. Note on Professor Brown's note. E. J. Stone.

Occultation of *Jupiter*, 1893 February 20, observed at the Durham University Observatory.

Errata to paper on meridian observations of *Sirius* and *Procyon* made at the Royal Observatory, Greenwich. W. G. Thackeray.

Note on the solution by least squares of the equations arising in the reduction of photographic star-plates. H. Jacoby.

Ephemeris for physical observations of *Mars*, 1896-97. A. Marth.

Observations of comet *a* 1896 (Perrine-Lamp) made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Some notes on the use and adjustments of the cœlostat. H. H. Turner.

May 8. Researches on the orbit of 42 *Comæ Berenices*=Σ 1728. T. J. J. See.

Further note on the light seen at Oxford on 1896 March 4. H. H. Turner.

Diameters of *Jupiter*, measured with the filar and double-image micrometers at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Ephemeris of the satellites of *Mars*, 1896-97. A. Marth.

Photographs of the spectra of twenty-three characteristic helium stars; also photographs of the spectra of six stars of the third magnitude, showing the transitions from type to type. F. McClean.

Observations of comet *a* 1896 (Perrine-Lamp) and *b* 1896 (Swift), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

June 12. Observations of phenomena of *Jupiter's* satellites with the 9½-inch Cooke equatorial refractor at Mr. Crossley's Observatory, Bermerside, Halifax, in 1895-96. J. Gledhill.

On certain phenomena presented by *Jupiter's* satellites and their shadows during transit; with a note on the

June 12. red spot, and on some methods of observing the transits of bright and dark spots across the central meridian. J. Gledhill.

Measures of the polar diameter and of the principal belts, and of two dark spots on *Jupiter*; and of satellites and their shadows in transit, made at Mr. Crossley's Observatory, Bermerside, Halifax, during the apparition of 1895–96. J. Gledhill.

Note on the period of *T Centauri*. A. W. Roberts.

Occultations of certain stars in *Præsepe* by the Moon on 1896 October 1, visible at Greenwich. Communicated by the Superintendent of the *Nautical Almanac* Office.

Cometary observations at the Liverpool Observatory in 1895. W. E. Plummer.

Galactic longitude and latitude of poles of binary star orbits. Alice Everett.

On the proper motion of B. D. +25°, No. 2874. W. W. Bryant.

An answer to certain questions asked in the *Bulletin Astronomique*, tome xiii., mai 1896, on time measurement. E. J. Stone.

Solar eclipse without instrumental means. E. J. Stone.

Note on a possible eclipse of *Jupiter's* second satellite by the shadow of the third, 1896 March 30. A. C. D. Crommelin.

Observations of comet *b* 1896 (Swift), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Meridian observations of comet *b* 1896 (Swift) at lower transit, made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the corrections to the right ascensions of stars derived from observations of the Sun made at Greenwich during the years 1836–95. W. G. Thackeray.

On the equipment of the astrophysical observatory of the future, with two appendices: Appendix I. On the support of large specula; Appendix II. On making the siderostat an instrument of precision. G. Johnstone Stoney.

Nov. 13. On the importance of accurately observing the *Leonids* this year. G. Johnstone Stoney.

On the comparison of reflector and portrait-lens photographs. E. E. Barnard.

Ephemeris for physical observations of *Jupiter*, 1896–97. A. Marth.

Data for computing the positions of the satellites of *Jupiter*, 1896–7. A. Marth.

Observations of comets and planets, made with the

Nov. 13. 15-inch Dunecht refractor and wire micrometer at the Royal Observatory, Edinburgh.

Observations of the phenomena of *Jupiter's* satellites at Windsor, New South Wales, in the year 1896. J. Tebbutt.

The Sidereal System : revised in 1896. Maxwell Hall.

Mercury. P. Lowell.

Determination of the rotation period and surface character of the planet *Venus*. P. Lowell.

Remarks on the physical observations of *Jupiter*, made at the Adelaide Observatory, 1884-93. E. P. Sells.

On the variation of uncanonical arbitrary constants; with an application to the planetary theory. A. Y. G. Campbell.

Mean areas and heliographic latitudes of Sun-spots in the year 1894, deduced from photographs taken at the Royal Observatory, Greenwich, at Dehra Dûn (India), and in Mauritius. Communicated by the Astronomer Royal.

Observations of comet *f* 1896 (Perrine), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

Note on the effects of distance upon the spectra of physical clusters of stars. E. J. Stone.

Observations of comet Perrine, 1896 Nov. 2, made at the Radcliffe Observatory, Oxford.

Photographic stellar spectra of the variable star *β Lyræ*, and also of types III. and IV. F. McClean.

Observation of comet Perrine 1895 IV., made at the Radcliffe Observatory, Oxford.

Dec. 11. Report on the expedition to Japan to observe the total solar eclipse of 1896 August 9. W. H. M. Christie, E. H. Hills, and H. H. Turner. Communicated by the Joint Permanent Eclipse Committee.

Report on the expedition to Norway to observe the total solar eclipse of 1896 August 9. A. A. Common. Communicated by the Joint Permanent Eclipse Committee.

Report to the Joint Permanent Eclipse Committee on the expedition to Kiö Island. J. Norman Lockyer. Communicated by the Committee.

Real paths of 101 meteors observed during the ten years ending November 1896. W. F. Denning.

Catalogue of real paths of large meteors. G. von Niessl.

Ephemeris for physical observations of the Moon, 1897. A. Marth.

Observations of minor planets made at Windsor, New South Wales. J. Tebbutt.

Comparison of the Sun's longitudes for 1901, computed from Newcomb's tables of the Sun, with those computed from Le Verrier's tables. A. M. W. Downing.

Dec. 11. Ephemeris of the *Leonids*, with introductory remarks. G. Johnstone Stoney.

On systematic errors in observing right ascensions of nebulæ. J. L. E. Dreyer.

The aurora of 1896 March 4. T. W. Backhouse.

Observation of Brooks' periodic comet, *c* 1896 (1889 V.), made at the Radcliffe Observatory, Oxford.

Observations of the solar eclipse, 1896 August 8–9, at Novaya Zemlya. E. J. Stone. Communicated by the Joint Permanent Eclipse Committee.

Observations of comet *f* 1896 (Perrine), made at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

On the inequality in the diurnal movement of stars due to refraction, and a method of allowing for it in astronomical photography. A. A. Rambaut.

Observations of the *Leonids* on 1896 Nov. 13 and 14. A. A. Rambaut.

1897 Jan. 8. Observations of the *Leonids*, made at the University Observatory, Oxford.

A method of clearing a lunar distance. F. C. Penrose.

Determination of the diameter and compression of the planet *Mars*, from observations with the Repsold heliometer of the Royal Observatory, Göttingen. W. Schur.

On the comparison of reflector and portrait lens photographs. Isaac Roberts.

Orbit of 44 Boötis ♅ I. 15=Sh. 193=Σ 1909. S. W. Burnham.

Note on the magnitude of *η Argûs*, 1896. R. T. A. Innes.

Heliographic co-ordinates of Sun-spots and faculæ on the Stonyhurst drawings. A. L. Cortie.

Note on Mr. A. Y. G. Campbell's paper "On the variation of uncanonical arbitrary constants, with an application to the planetary theory." Sir R. S. Ball.

On differential refraction to terms of higher order than the first. H. H. Turner.

Observations of comet 1896 I. (Perrine-Lamp), made at the Radcliffe Observatory, Oxford. Communicated by E. J. Stone.

Notes on meteors observed at Penarth, Glamorgan, on 1896 November 14. G. C. Thompson and H. W. L. Tanner.

Observations of occultations of stars by the Moon, and phenomena of *Jupiter's* satellites, made in the year 1896, at the Royal Observatory, Greenwich. Communicated by the Astronomer Royal.

List of Public Institutions and of Persons who have contributed to the Library, &c., since the last Anniversary.

Her Majesty's Government in India.
The Lords Commissioners of the Admiralty.
The French Government.
The Italian Government.
The Norwegian Government.
British Association for the Advancement of Science.
British Astronomical Association.
British Horological Institute.
Camera Club.
City of London College.
Geological Society of London.
London Mathematical Society.
Meteorological Office.
Physical Society of London.
Royal Geographical Society.
Royal Institution of Great Britain.
Royal Meteorological Society.
Royal Observatory, Greenwich.
Royal Photographic Society of Great Britain.
Royal Society of London.
Royal United Service Institution.
Society of Arts.
University College, London.
Belfast Natural History and Philosophical Society.
Birmingham Natural History and Philosophical Society.
Cambridge Observatory.
Cambridge Philosophical Society.
Cambridge University Press.
Cardiff, Astronomical Society of Wales.
Dublin, Royal Irish Academy.
Dublin, Royal Society.
Dunsink Observatory.
Edinburgh, Royal Observatory.
Edinburgh, Royal Society.
Galway, Queen's College.
Kew Observatory.
Leeds Astronomical Society.
Leeds Philosophical and Literary Society.
Liverpool Literary and Philosophical Society.

Liverpool Observatory.
Manchester Literary and Philosophical Society.
Oxford, Radcliffe Observatory.
Rugby School Natural History Society.
Stonyhurst College Observatory.
Truro, Royal Institution of Cornwall.
Adelaide Observatory.
Amsterdam, Royal Academy of Sciences.
Arcetri, Royal Observatory.
Athens, National Observatory.
Australasian Association for the Advancement of Science.
Baltimore, Johns Hopkins University.
Batavia, Magnetical and Meteorological Observatory.
Batavia, Royal Society of Natural History.
Belgium, Royal Observatory.
Berlin, Central International Geodetic Bureau.
Berlin, German Transit of Venus Commission.
Berlin, Physical Society.
Berlin, Royal Astronomical Computation Institute.
Berlin, Royal Observatory.
Berlin, Royal Prussian Academy of Sciences.
Berlin, Royal Prussian Geodetic Institute.
Berne University.
Bologna, Royal Academy of Sciences.
Bombay Branch of the Royal Asiatic Society.
Bombay Government Observatory.
Bordeaux, Society of Physical and Natural Sciences.
Boston, American Academy of Arts and Sciences.
Brisbane, Royal Geographical Society of Australasia.
Brussels, Astronomical Society of Belgium.
Buda-Pesth, Hungarian Academy of Sciences.
Buda-Pesth, Royal Hungarian Institute for Meteorology and Terrestrial Magnetism.
Buenos Aires, Argentine Meteorological Office.
Calcutta, Asiatic Society of Bengal.
Calcutta, Surveyor-General of India.
Canada, Geological Survey.
Cape of Good Hope, Geodetic Survey of South Africa.
Cape of Good Hope, Royal Observatory.
Cape Town, South African Philosophical Society.
Catania Observatory.
Chicago, Academy of Sciences.
Coimbra Observatory.
Copenhagen, Royal Danish Academy of Sciences.
Cordoba, Argentine National Observatory.
Cracow, Academy of Sciences.
Dorpat, Imperial University Observatory.
Georgetown College Observatory.
Göttingen, Royal Society of Sciences.
Halifax, Nova Scotian Institute of Sciences.

Halle, Imperial Leopold-Caroline Academy.
Harvard College Astronomical Observatory.
Helsingfors, Geographical Society of Finland.
Helsingfors, Society of Sciences of Finland.
Hongkong Observatory.
Italian Meteorological Society.
Kalocsa Observatory.
Karlsruhe Observatory.
Leiden Observatory.
Leipzig, Astronomical Society.
Leipzig, Prince Jablonowski Society.
Leipzig, Royal Society of Sciences of Saxony.
Lick Observatory.
Lisbon, Royal Observatory.
Lund Observatory.
Madrid Observatory.
Madrid, Royal Academy of Sciences.
Manila Observatory.
Mauritius, Royal Alfred Observatory.
Melbourne Observatory.
Melbourne, Royal Society of Victoria.
Moscow, Imperial Society of Naturalists.
Munich, Royal Bavarian Academy of Sciences.
Naples, Academy of Physical and Mathematical Sciences.
Natal Observatory.
O-Gyalla, Central Meteorological and Magnetical Observatory.
Ottawa, Royal Society of Canada.
Padua Observatory.
Padua, Royal University.
Paris, Academy of Sciences.
Paris, Astronomical Society of France.
Paris, Bureau of Longitude.
Paris, General Depôt of Marine.
Paris, Mathematical Society of France.
Paris Observatory.
Paris, Philomathic Society of France.
Paris, Polytechnic School.
Philadelphia, American Philosophical Society.
Philadelphia, Franklin Institute.
Pola, Meteorological and Magnetical Observatory.
Prague, Imperial Observatory.
Rio de Janeiro Observatory.
Rome, Central Meteorological Office.
Rome, Italian Spectroscopic Society.
Rome, Pontifical Academy *dei Lincei*.
Rome, Royal Academy *dei Lincei*.
St. Petersburg, Astronomical Society of Russia.
San Francisco, Astronomical Society of the Pacific.
Stockholm, Royal Swedish Academy of Sciences.

Strassburg, Imperial University Observatory.
Sydney, Royal Society of New South Wales.
Tacubaya, National Astronomical Observatory.
Tasmania, Royal Society.
Tiflis, Physical Observatory.
Toronto, Astronomical and Physical Society.
Toronto, Canadian Institute.
Toronto University.
Toulouse, Academy of Sciences.
Turin, Royal Academy of Sciences.
Upsal Observatory.
Vienna, Austrian Geodetic Commission.
Vienna, Imperial Academy of Sciences.
Vienna, Imperial Ministry of Marine.
Vienna, von Kuffner Observatory.
Virginia, Leander McCormick Observatory.
Washburn Observatory of the University of Wisconsin.
Washington, National Academy of Sciences.
Washington, Office of the American Ephemeris.
Washington, Philosophical Society.
Washington, Smithsonian Institution.
Washington, United States Coast and Geodetic Survey.
Washington, United States Naval Observatory.
Yale University Astronomical Observatory.
Zurich, Central Meteorological Institute of Switzerland.
Zurich, Natural History Society.
Editors of the "American Journal of Mathematics."
Editors of the "American Journal of Science."
Editor of the "Astronomical Journal."
Editor of "Astronomische Mittheilungen."
Editor of the "Astronomische Nachrichten."
Editors of the "Astrophysical Journal."
Editor of the "Athenæum."
Editors of the "Bulletin des Sciences Mathématiques."
Editor of the "English Mechanic."
Editor of "Himmel und Erde."
Editor of "Indian Engineering."
Editor of the "Naturwissenschaftliche Rundschau."
Editors of the "Observatory."
Editor of "Popular Astronomy."
Editor of "Sirius."

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Sigr. A. M. Antoniazzi.
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W. H. Wesley, Esq.
Henry Wilde, Esq.
Prof. Max Wolf.
Dr. A. Wolfer.

ADDRESS.

Delivered by the President, A. A. Common, LL.D., F.R.S., on presenting the Gold Medal to Professor E. E. Barnard.

Your Council have this year awarded the Gold Medal of the Society to Professor Edward Emerson Barnard, for his discovery of the fifth satellite of *Jupiter*, his celestial photographs and other astronomical works, and, according to custom, it becomes my pleasant duty to state more fully the circumstances that have influenced the Council in making this award.

[Before proceeding with his address the President expressed his deep regret that Professor Barnard was not present at the meeting. He had left New York on February 2 in order to be present on this occasion, but his ship, the *Trave*, had not yet arrived, and the fact that other Atlantic liners were overdue made it probable that there had been some rough weather causing the delay. As events proved, this surmise was correct, the *Trave* reaching Southampton after midnight the same night, February 12.]

The discovery of the fifth satellite of *Jupiter* (certainly the most important discovery of the last twenty years) is the product of three factors—a good telescope, a good sky, and a good observer. To the munificence of James Lick the telescope on Mount Hamilton is due, and, without detracting in the slightest degree from the credit that is due to Professor Barnard for his magnificent discovery, a large share of honour remains to James Lick and the maker of the telescope, George Alvan Clark. Without this particular combination of men it is not too much to say that the fifth satellite would yet remain to be discovered. We may congratulate our medallist on having the opportunity of using the Lick telescope, and we may certainly also congratulate the donor and the maker on having secured an observer like Professor Barnard to do justice to the telescope. Though since its discovery it has been seen by other observers in America and a few in England, yet, as was pointed out by Sir John Herschel, the difference between seeing an object already known to be there and discovering that object is very great, and, moreover, although the satellite has been seen by others, with the exception of Hermann Struve at Pulkowa, they have been unable

to measure its position. Our knowledge of its orbit is due almost entirely to the observations of Professor Barnard himself. I do not know that I can demonstrate the magnitude of Professor Barnard's especial achievement more clearly than by calling to mind that his friend, Professor S. W. Burnham, our medallist of three years ago, had shared with him the advantages of telescope and climate for some years, and yet the satellite remained unknown.

To us the news of the discovery was announced from Mount Hamilton in the following telegram :—"Professor Holden announces that the Lick telescope has revealed the existence of a fifth satellite to *Jupiter* with a period of $12^h\ 36^m$. Its distance from the centre of the planet is 112,400 miles, and its light compares with that of a star of the thirteenth magnitude," published on 1892 September 13 (the satellite having been discovered on September 9), which was followed by a later telegram, informing us that Professor Barnard had made the discovery, and placing the period at $17^h\ 36^m$. The confusion that arose from these telegrams was not cleared up till about October 16, by the receipt of the *Astronomical Journal* of October 4, No. 275, in which Professor Barnard gives an interesting account of his discovery of this satellite, with the measurements he had made.

From the elongations he deduced a period of $11^h\ 49^m{\cdot}63$, but as this was only from measurements obtained between September 9 and 14, it was, of course, only a first, but, considering the extreme difficulty of the object, a very close approximation. Later observations made by Professor Barnard have enabled the period to be better determined at $11^h\ 57^m\ 22^s{\cdot}60$.

He has given a most interesting account of his discovery and a diagram showing the relative size of the satellite as compared with the other four. He estimates the diameter at about the $\frac{1}{200}$th part of the diameter of *Jupiter*, and states that a magnification which raised the other four satellites to veritable moons failed to increase the diameter of the fifth. This little body stands quite by itself in the Jovian system. In the recently published volume iv. of his *Mécanique Céleste* our late lamented Associate, M. Tisserand, remarks that the theory of its motion must be discussed quite apart from those of the other four, whose movements it is probably too small to influence seriously. Had it been larger, and our knowledge of the motions of the other four more completely worked out, it is conceivable that we might have got some suspicion of its presence from theoretical considerations, but it is noteworthy that neither in this way nor in any other was the actual discovery led up to. In the case of *Hyperion* there was a marked gap in the already complex Saturnian system which suggested the possibility of another satellite, but we had become so thoroughly accustomed to the well-established Jovian system that it must have required a positive effort to conceive the possibility of an addition to it, and

in this way I regard the discovery of Professor Barnard as most remarkable.

I have alluded to the discovery of *Hyperion*; and, in fact, our minds, on such an occasion as the present, naturally turn to others of the same character.

Besides the fifth satellite of *Jupiter*, our century has produced six new satellites, of which four belong to those red-letter years 1846 and 1847, which added to the solar system *Neptune* and his satellite, two new satellites of *Uranus* and one (*Hyperion*) of *Saturn*. William Lassell, who had the whole credit of two of these discoveries, and a share in that of the others, received our medal in 1849 from the hands of Sir John Herschel "for the construction of his equatorial instrument and the discoveries made with it." The prominence given to the construction of the instrument bears out what I have already ventured to say above. In his presidential address, Sir John Herschel quoted an official report to the following effect:—"The simple facts are that Mr. Lassell cast his own mirror, polished it by machinery of his own contrivance, mounted it equatorially in his own fashion, and placed it in an observatory of his own engineering; that with this instrument he, a private man, of no large means, in a bad climate, discovered the satellite of *Neptune*, the eighth satellite of *Saturn*, and re-observed the satellites of *Uranus*."

Thirty years elapsed before any more new satellites were brought to our knowledge, and then Professor Asaph Hall (aided by the same constructive skill as that which enabled our present medallist to make his brilliant discovery, that of the Alvan Clarks) announced the two satellites of *Mars*. In 1879 he received our Medal for this great achievement from the hands of Lord Lindsay, now Lord Crawford. It is by the side of these men—one an Englishman, of whom we are justly proud, and the other a fellow-countryman of his own, in whom he doubtless has a similar national pride—that Professor Barnard now takes his place; and, in recognition of his right to this place, your Council has conferred upon him the highest honour in its power. Although the number of satellite discoveries credited to these three men shows a progressive decrease from four to two and from two to one (a minimum which it is, however, impossible to further reduce in the future), the quality of the achievement must on the other hand progressively rise; for it may be confidently asserted that each new discovery is harder than those preceding it. Moreover, our present medallist has other claims of an equally high character on the respect and admiration of astronomers. The terms of the formal award include his photographs and other astronomical work. But before passing to these I will venture to follow the example set by Lord Lindsay on the occasion to which I have already referred, in giving some account of the life of the man whom we hoped to have seen among us to-day. Lord Lindsay remarked that Mr. Asaph Hall's early history afforded "a bright example of what per-

severance and determination may effect in overcoming even the most adverse circumstances," and this is equally true of our present medallist. Indeed, when we consider the life-histories of astronomers who have become famous, we cannot but be struck with their general similarity. In so many cases they have become astronomers, not through the action of outside forces, but very often in spite of them, and simply from their own determination. Professor Barnard's early life, as described* by his friend, S. W. Burnham, is like that of many other notable astronomers, but with every turn accentuated to a degree almost romantic.

He was born at Nashville, Tennessee, in 1857. His early education was limited to two months' attendance at a common school, and such instruction as his excellent mother could give him at home. Fatherless and destitute at the close of the war, he began at the age of eight or nine to work in a large photographic studio in Nashville, and soon became a faithful and accomplished assistant to his employers. The loan by a friend of Dr. Dick's book, the *Practical Astronomer*, in 1876, awakened a love for astronomy which soon grew into a passion. The use of a 1-inch cheap lens roughly mounted in a tube of his own construction showed him something of what a telescope would do; and the visit of a travelling showman to Nashville, with a small glass for street exhibition, further stimulated him to acquire as good an instrument as he could for himself. Accordingly, by practising the most rigid economy he was enabled in 1877 to purchase a 5-inch telescope, and it is significant that his first systematic work of any importance was a careful study of the planet *Jupiter*. In 1881 he began to search for new comets with his 5-inch, and discovered one on September 17 of that year. This was followed a year after by another, and in 1884 he found a comet of period 5·4 years. The next year, 1885, yielded two new comets, 1886 one, and 1887 three more; and in the five succeeding years he found altogether eleven comets, one of them (1892 V.) being another new comet of short period (6·30 years). One notable result of this success was that he several times obtained the prize of 200 dollars offered by Mr. Warner for the discovery of a new comet, and was thus enabled to buy books and other accessories and to pursue his studies with fewer financial anxieties.

In 1883 he left the photographic business, having received a Fellowship in Astronomy at the Vanderbilt University. During the preceding years he had given all his spare time to study, working in the daytime and studying alone at night. It is easy to mention these facts in a few words, but not so easy to give an idea of all that they mean—the continuous and courageous struggle against adverse circumstances of all kinds. He now utilised to the full the opportunities afforded by the University in the time he spared from the hard work at the 6-inch equa-

* *Popular Astronomy*, and *Harper's Magazine*, September, 1893.

torial, which resulted in the cometary discoveries above mentioned, and in many others, such as new nebulæ and double stars. To one of these last I shall refer presently.

In 1888 he was offered a position in the Lick Observatory, then about to be opened with the largest equatorial in the world, in a climate of which Professor Barnard is wont to speak with an almost reverent enthusiasm; and the able way in which he availed himself of these advantages is now familiar matter of history. With one notable exception (that of the Sun) every description of celestial object has come under his scrutiny, and his skill as an observer is only equalled by his skill as a photographer. And after thus briefly reviewing his career, I now return to his work, and especially to his photographs, which are definitely mentioned in the terms of the award of the Medal.

The astronomical photographs which Professor Barnard has made are chiefly of comets and of the Milky Way, taken with the "Willard" lens of the Lick Observatory, having an aperture of 6 inches and a total length of 31 inches. These latter are perhaps the finest examples of star photography extant. Moreover, they are the *first photographs* made to show the structure of the Milky Way. Many observers have made eye investigations on the distribution of the stars in the Milky Way. Amongst others we may note those elaborate representations of the galaxy south of 12°·5, which became accessible in 1877 by the Atlas of the *Uranometria Argentina* of Dr. Gould and his assistants at Cordoba, followed by the elaborate map which Dr. Boeddicker prepared at Lord Rosse's observatory. These, with the drawing by Mr. Trouvelot, and the earlier drawing made by Sir John Herschel at the Cape of Good Hope, represent the attempts made to delineate the Milky Way by the pencil, and any one working at the distribution of stars in the Milky Way will naturally use these drawings for comparison.

Personally I have little doubt of the essential inferiority of the drawings to the photographs, and, though it may be of some interest to know the points of difference, I cannot but think that photographs such as those of Professor Barnard are the only safe ground in such an investigation.

With regard to the comet photographs, our medallist has the credit of having made the first discovery of a comet by photography, an event which, of course, was bound to come sooner or later, but for which full credit may freely be granted to the first in the field. The series of photographs of comets taken by Professor Barnard, showing, as they do, the rapid changes that take place in comets' tails, are of great value. He has also actually obtained meteor trails on his photographic plates. Exposing plates on 1890 August 9, 10, and 11, he got traces of the trails of meteors, and on one of the plates of Brooks' Comet, taken on 1893 November 13, there is a very fine trail of a meteor. Finally, with a small lens of short focus,

Professor Barnard discovered the great nebula surrounding the belt of *Orion*.

We have in the library of this Society some sixty glass photographs presented by Professor Barnard, positive copies made with his own hands of some of his photographs. An inspection of these beautiful pictures, which are, I trust, well known to most of us, will reveal their merits far better than any description I can give, and I will offer but one further remark on the photographic work of our medallist. In the case of his discovery of the fifth satellite, we saw that there were at least three important factors, without any one of which success could not have been attained. But in the photography of our medallist, and in much of his other work, the external factors have less significance, and the results may be claimed almost entirely by the observer himself. Professor Barnard has shown us with what modest means good results can be obtained—with not only a small but a cheap lens, such as may be found in any magic lantern. No doubt his early experiences, of which I have spoken, were valuable in giving him this knowledge of what can be done with humble apparatus ; but we must certainly admire, not merely the skill, but the courage of a man who could, under the very shadow of the great 36-inch refractor, demonstrate the merits of a lens which could be bought for a few shillings.

Such a demonstration we might have naturally awaited from a man whose instrumental equipment was necessarily small, or who could not use a large telescope to advantage ; that it should come from Professor Barnard, who had not only the opportunity of using the great refractor, but conspicuous ability for such work, is proof not only of his untiring industry, but of his thoroughly unprejudiced mind.

To summarise the other work of our medallist is a matter of some difficulty, owing to its enormous amount and its varied character. Up to the end of last year he had published twenty-six papers in the *Monthly Notices*, eighty-five in the *Astronomische Nachrichten*, seventy-five in the *Astronomical Journal*, and seventy-four in other American papers connected with astronomy, including an important report on the eclipse of 1889 January 1, published by the Lick Observatory. These represent, in nearly every case, work done at the telescope, and show him a brilliant and untiring observer of the very first order. I shall make no attempt at completeness, but shall merely endeavour to illustrate his extraordinary keenness in observing and his versatility ; and as a first illustration, I will mention his independent discovery in 1883 of that singular phenomenon called the "Gegenschein." This was discovered many years ago by a German astronomer, though its cause is still a mystery, and even now but few astronomers, though they know what to look for, have ever seen it. That our medallist should have independently discovered it, having no knowledge of it previously, is testimony to observing skill of the highest quality ; and the fact that he himself, as I understand,

estimates the discovery as a piece of his very best work is in itself very significant. In the same year he accomplished a unique performance in double-star astronomy. Noticing that the star *β Capricorni* disappeared at occultation by the Moon, not instantaneously, but gradually, he had sufficient confidence in his observation to ask for scrutiny of this star with the most powerful instruments available, and ultimately, with the 18½-inch equatorial of the Dearborn Observatory at Chicago, his friend S. W. Burnham found the star to be a close and unequal double, which, as Professor Burnham himself remarked, "taxed the powers of that splendid instrument to show even to a trained eye."

To the cometary discoveries of our medallist already mentioned, it must be added that in 1889 August he discovered four satellites of Brooks' comet, and that he has followed faint comets long after they had become invisible in other instruments, notably Brooks' comet of 1889, which was observed by him nearly a year longer than by any other observer ; and again, the comet discovered by himself in 1888, which he followed for over two years—the longest duration of visibility known. Such observations suggest the possibility of following some of the periodic comets all round their orbits, though it must be confessed that we are still far from the realisation of this hope.

Again, he has classified periodical comets by their visual appearance, so that on several occasions he has been able to tell a short-period comet at the first glimpse in the telescope.

In addition to the photographic discovery of new nebulæ, he has discovered many with the telescope ; he has made many observations of the surfaces of the planets *Mars*, *Jupiter*, *Saturn*, and of *Jupiter's* satellites (some of which are yet unpublished), particularly the very important one of the first satellite of *Jupiter*, showing the presence of dark polar caps and a white equatorial band, an observation of the utmost delicacy and importance, particularly in the light of the anomalous appearance attributed to this satellite.

Working with the 12-inch as well as the 36-inch telescope of the Lick Observatory, he has made a series of measurements of the diameters of the major planets and of their satellites, as well as of *Mercury* and *Venus*, and the first four Asteroids and many measurements of *Saturn's* rings. His measurements of double stars are not yet all published, but they include remeasurements of many of Burnham's difficult doubles. In addition he has discovered many others, as for instance, the most delicate double star connected with the trapezium of *Orion* and *β Capricorni*, which I have already mentioned.

I trust that these instances, not exhaustive, but tolerably representative, will be sufficient to show that the claims of Professor Barnard to the honour now conferred upon him are both strong, diverse in character, and very numerous.

It would, indeed, be a thankless task to attempt a complete account of his work, for the completeness would certainly be lost

in a very short time. Professor Barnard is in the presence of new opportunities which we all feel sure will add to his triumphs. He has left Mount Hamilton, but he has only exchanged one big telescope for another, and when the Yerkes refractor is ready, we may confidently expect news from Chicago of the kind with which he has made us familiar in the past.

The President then addressed the Foreign Secretary as follows :—Dr. Huggins :—I hope that it will not be necessary to ask you to forward this Medal to Professor Barnard, but that you will, within a very short time, be able to hand it to him. In doing so, I will ask you to express our great appreciation of his past work, and our very best wishes for his success in the future.

I have another pleasant duty to perform : to mention an award now made for the first time. This arises from a bequest by the late Mrs. Jackson-Gwilt, and consists, as the Fellows are no doubt aware, of a bronze medal and a gift of money.

Your Council have awarded this gift to Mr. Lewis Swift ; and I am sure that I need not say anything to you of Mr. Swift's astronomical labours, nor of the peculiar circumstances that will, I hope, make the gift doubly acceptable to him. In fact, as I have the opportunity of setting the precedent in this matter, I propose to refrain from giving an address ; for, though the Society has been accustomed to hear an address read in reference to the award of the Gold Medal, I think that there are reasons why the custom should not be followed in the case of this gift, and so I will only ask the Foreign Secretary to forward this medal and the gift to Mr. Swift, with the best hope of the Society that better times may come to him.

The meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :

President.

Sir R. S. BALL, M.A., LL.D., F.R.S., Lowndean Professor of Astronomy and Geometry, Cambridge.

Vice-Presidents.

A. A. COMMON, Esq., LL.D., F.R.S.
G. H. DARWIN, Esq., M.A., LL.D., F.R.S., Plumian Professor of Astronomy, Cambridge.
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Foreign Secretary.

WILLIAM HUGGINS, Esq., LL.D., D.C.L., F.R.S.

Council.

Capt. W. DE W. ABNEY, C.B., R.E., D.C.L., F.R.S.
W. H. M. CHRISTIE, Esq., M.A., F.R.S., Astronomer Royal.
A. M. W. DOWNING, Esq., M.A., D.Sc., F.R.S., Superintendent of the *Nautical Almanac*.
F. W. DYSON, Esq., M.A.
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Capt. E. H. HILLS, R.E.
W. H. MAW, Esq.
Capt. WILLIAM NOBLE.
G. M. SEABROKE, Esq.
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E. J. STONE, Esq., M.A., F.R.S., Radcliffe Observer.
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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. MARCH 12, 1897. No. 5

SIR R. S. BALL, LL.D., F.R.S., PRESIDENT, in the Chair.

J. Harold Herbert, C.E., Hazlemont, The Boulevard, Nottingham, was balloted for and duly elected a Fellow of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Arthur W. Clayden, M.A., F.G.S., F.C.S., F.R.Met.Soc., Principal of the Exeter Technical and University Extension College (proposed by Wm. Ellis) ;

Herbert Lovis Noel Noel-Cox, 2 Edinburgh Mansions, Victoria Street, S.W. (proposed by Richard Inwards).

One hundred and thirty-seven presents were announced as having been received since the last meeting, including amongst others :—

G. C. Comstock, studies in spherical and practical astronomy ; W. T. Lynn, Celestial Motions, 9th edition ; Remarkable Comets, 5th edition ; Remarkable Eclipses, 2nd edition ; T. J. J. See, Researches on the evolution of the stellar systems, vol. i. ; presented by the authors ; Report of the observations of the total solar eclipse 1896 August 9, in Novaya Zemlya, and lantern slides of the Corona, from negatives by MM. Kostinsky and Hansky, presented by M. Kostinsky ; Series of 12 enlarge-

ments from negatives of portions of the lunar surface, presented by the Lick Observatory; Photographs of the Great Sun-spot of 1897 January, presented by G. J. Newbegin.

Also twenty-five works from the library of the late Mr. Sidney Waters, and an equatorially-mounted camera with telephotographic lens, prepared for the observation of the total eclipse of 1896, presented by Mrs. Waters.

On the Mean Motions of the Lunar Perigee and Node.

By Professor Ernest W. Brown, M.A.

The following is a brief abstract of the paper:

The calculations necessary for obtaining a new development of the lunar theory having progressed to a stage at which it is possible to obtain very approximate values of the mean motions of the perigee and node of the Moon, it is of some interest to see how the results compare with those of Delaunay and Hansen. The motions are now obtained so as to include the second powers of the eccentricities and inclination. The remaining parts are estimated from Delaunay's results. Using Dr. Hill's values for the parts due to the figure of the Earth, the results are:

Mean annual motion of Perigee	$+146\ 435''.3$,
„ „ „ Node	$-\ 69\ 679''.5$;

with a possible error not exceeding $2''$ in the case of the perigee, and $1''$ in the case of the node. Hansen's results, when corrected for the part depending on the figure of the Earth, give

$$+146\ 434''.9,$$
$$-\ 69\ 677''.3.$$

The observations give

$$+146\ 435''.6,$$
$$-\ 69\ 679''.5.$$

It appears that the difference of $2''.2$ which Hansen found in the case of the node is at least partly due to some error. Nothing can be said as yet concerning the question as to whether the Newtonian law is exact, an hypothesis treated by Professor Newcomb in his "Astronomical Constants." He finds that a difference of $+1''.40$ would result in the case of the perigee. The corrected value of Hansen gives only $+0''.7$, while that which I have obtained is $+0''.3$, but the error of the last result may possibly be as great as $2''$. The question awaits the deter-

mination of the higher terms due to the Sun's action—a determination which I hope to make in the course of a year or two.

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1. Up to the present time, the only theoretical values of the mean motions of the lunar perigee and node which even pretend to be accurate to one seventy-thousandth part of the whole, are those derived by Hansen. Delaunay's algebraical developments, though carried in some cases to a high power of the ratio of the mean motions, are quite insufficient, and doubts have been thrown on the accuracy of his higher terms.

Apart from the question of the formation of tables for the Moon's motion, there is the interesting one which Professor Newcomb has brought forward in his "Astronomical Constants" as to whether the Newtonian law of gravitation requires any modification. The supposition made is that the force with which one body attracts another does not vary as the exact inverse second power of the distance, but that the index differs from -2 by some very small fraction. By assuming the index to be $-2{\cdot}0000001574$, the differences between theory and observation in the cases of the perihelia of *Mars* and *Mercury* are fairly well accounted for (*op. cit.* p. 119), the effects on those of the other planets not being at present within the range of observation. But the same number will cause an addition to the annual mean motion of the lunar perigee of $+1''{\cdot}40$; the effect on the motion of the nodes is insensible. The comparison of the numbers given by Hansen shows a difference of $+1''{\cdot}56$ for the perigee, but Professor Newcomb adds that the argument loses all sustaining force on account of a difference of nearly $3''$ in the case of the node. Thus, either Hansen's values are not accurate, or some other cause affects the motion of the node.

2. My calculations of the solar inequalities in the Moon's motion having reached a stage at which it is possible to obtain the theoretical values of these mean motions accurately as far as the second order inclusive, in relation to the eccentricities and inclinations, it is interesting to see, first, how Delaunay's algebraical results appear as to accuracy and convergence; secondly, how Hansen's numerical results appear as to accuracy; thirdly, whether any fresh light can be thrown on the hypothesis mentioned above. In the new results given below, the question of convergence, from a practical point of view, does not enter at all; for the results are obtained by using the *numerical* value of the ratio of the mean motions of the Sun and Moon (a ratio known from observation with great accuracy), the values of the other constants only being inserted at the end of the work. The series for the quantities under consideration here when arranged according to powers of the squares of the eccentricities, inclination, and ratio of the parallaxes, diminish so rapidly that it is quite unnecessary to proceed further than the fourth powers of these constants, while those of this order are very small.

3. In order that the degree of accuracy obtained may be clearly defined, I give below a detailed comparison of the new results with those obtained by Delaunay, and also a comparison of the whole with those derived by Hansen from theory and observation. Delaunay's numerical results being given in terms of the *daily* motions, I use the latter for the discussion of them, returning to *annual* motions when the final general values are to be considered. The word "order" used below refers only to powers of the eccentricities, inclination, and the square root of the ratio of the parallaxes (this ratio being really a small quantity of the second order), and not to powers of the ratio of the mean motions.

4. As the terms of the fourth order are as yet undetermined (using the word "order" in the sense just explained), it is necessary to deduce their values from the results given by Delaunay. That these may be as accurate as possible, before proceeding to the main discussion, I give a test of their accuracy. Estimation is made of the remainders in each case. It is right to state here that these estimations were made in such a way that any conscious or unconscious influence which a knowledge of the result required for agreement with observation would have caused, was eliminated by one or two artifices. The possible errors have intentionally been made large, so that no false idea as to the accuracy of the final results might be entertained.

5. Although no positive evidence for or against the hypothesis treated by Professor Newcomb is obtained, one result seems to be demonstrated, namely, that the value obtained by Hansen for the annual motion of the node is at least one, if not two, seconds in error. Further, if his value for the part of the motion of the perigee which depends on the solar action is correct, one half of the small difference between theory and observation can be accounted for by using Dr. Hill's instead of Hansen's value for the part depending on the figure of the Earth. This, however, tells nothing definite, for if doubts are thrown on the accuracy of Hansen's calculations for the motion of the node, we are not entitled to assume the accuracy of the result for the perigee. The most probable theoretical values for both these motions are given at the end of the paper.

A Test of Delaunay's Expressions.

6. In a paper which will shortly appear in the Proceedings of the London Mathematical Society, the following results are shown to hold when the square of the ratio of the solar to the lunar parallax is neglected.

$$c_1 + c_2\frac{\partial \pi_1}{\partial n} + c_3\frac{\partial \theta}{\partial n} = \frac{3}{2}(\mathrm{E}+\mathrm{M})\frac{\partial}{\partial n}\left(\frac{1}{r}\right)_0,$$

$$c_2\frac{\partial \pi_1}{\partial \cdot e^2} + c_3\frac{\partial \theta_1}{\partial \cdot e^2} = \frac{3}{2}(\mathrm{E}+\mathrm{M})\frac{\partial}{\partial \cdot e^2}\left(\frac{1}{r}\right)_0,$$

$$\frac{\partial \pi_1}{\partial \cdot \gamma^2} + c_3\frac{\partial \theta_1}{\partial \cdot \gamma^2} = \frac{3}{2}(\mathrm{E}+\mathrm{M})\frac{\partial}{\partial \cdot \gamma^2}\left(\frac{1}{r}\right)_0.$$

Here c_1, c_1+c_2, $c_1+c_2+c_3$ are the values of Delaunay's final variables L, G, H, after all the periodic terms have been eliminated ;* π_1, θ_1 are the mean motions of the perigee and node ; $E+M=n^2a^3$ is the sum of the masses of the Earth and Moon, and $\left(\frac{1}{r}\right)_0$ denotes the constant term in the value of $1/r$ when the latter is exhibited as a sum of periodic terms depending on the time. All the quantities are supposed to be expressed in terms of Delaunay's final constants n, a, e, γ, e', a', n'.

With the help of the expression for the constant part of the parallax given by Adams, † these equations may be used to verify Delaunay's results. The values of L, G, H, and thence those of c_1, c_2, c_3 in terms of the final constants, have been deduced by Professor Newcomb.‡ Since Delaunay does not make use of any similar verification equations, I have thought it worth while to test his results as far as it was possible with Adams' expression. The highest power of m tested is given in each case.

Test of the values of c_1, c_2, c_3, given by Professor Newcomb on p. 184 of the memoir just referred to. The value of c_1 is tested completely except for the part depending on a^2/a'^2. The value of c_2 contains e^2 as a factor of all its terms. It is tested as far as e^2m^3, e^4m^1 ; there are no terms involving $e^2\gamma^2m^0$, $e^2\gamma^2m^1$, $e^2e'^2m^0$, $e^2e'^2m^1$. The value of c_3 contains γ^2 as a factor of all its terms. It is tested as far as γ^2m^3, $\gamma^2e^2m^1$; there are no terms involving $\gamma^2e'^2m^0$, $\gamma^2e'^2m^1$, γ^4m^0, γ^4m^1.

We now come to the motions of the perigee and node. It is only possible to test these to a low power of m in any case. Every term tested was found correct. As the numerical values of the terms which contain e^2, γ^2, e'^2 as factors are given below, no detailed statement is necessary. But as Delaunay's values for the terms of higher orders are used, I give the results obtained.

The equation most convenient for these terms is

$$\frac{\partial c_2}{\partial \cdot \gamma^2}\cdot\frac{\partial \pi_1}{\partial \cdot e^2}+\frac{\partial c_3}{\partial \cdot \gamma^2}\cdot\frac{\partial \theta_1}{\partial \cdot e^2}-\frac{\partial c_2}{\partial \cdot e^2}\cdot\frac{\partial \pi_1}{\partial \cdot \gamma^2}-\frac{\partial c_3}{\partial \cdot e^2}\cdot\frac{\partial \theta_1}{\partial \cdot \gamma^2}=0,$$

which is deducible directly from the second and third of the equations given above.

In the motion of the perigee the terms involving $e^2\gamma^2m^2$, $e^2\gamma^2m^3$, γ^4m^2, γ^4m^3, $\gamma^2e^2m^2$, $\gamma^2e^2m^3$, $\gamma^2e'^2m^2$, $\gamma^2e'^2m^3$, were tested and found correct. In the motion of the node, the terms involving e^4m^2, e^4m^3, $e^2\gamma^2m^2$, $e^2\gamma^2m^3$, $e^2e'^2m^2$, $e^2e'^2m^3$ were tested and found correct. It will be noticed that these terms include all the larger terms given in the tables below for terms of the fourth order, except those depending on a^2/a'^2.

* *Théorie de la Lune*, vol. ii. pp. 235, 236.

† *M.N.R.A.S.* vol. xxxviii. *Coll. Works*, p. 203.

‡ Papers published for the use of the Amer. Eph. vol. v. pp. 184, 201, 202.

The Motion of the Perigee.

7. *Term of Zero Order.*—This has been completely obtained and discussed by Dr. G. W. Hill * and M. Andoyer. † The value which results from the numerical determination made by the former is,

Daily Motion, +406″·6402.

8. *Terms of the Second Order.*—The following table gives the daily motions obtained by Delaunay, ‡ arranged according to the powers of m, the ratio of the mean motions. As usual, e, γ, e' are the constants defined in Delaunay's manner.

Daily Motions.

Factors.	e^2	γ^2	e'^2
	″	″	″
m^2	−0·3000	−3·2085	+0·0840
m^3	− ·6311	− ·9450	+ ·1440
m^4	− ·2763	− ·3705	+ ·0998
m^5	− ·1213	− ·1466	+ ·0539
m^6	− ·0387	...	...
m^7	+ ·0006	...	...
Sum	−1·3668	−4·6706	+0·3817
Est. Rem.	+ ·004	− ·07	+ ·05
Delaunay	−1·36	−4·74	+0·43
True value	−1·4218	−4·7627	+0·4278

The part contributed by the term of any order in relation to e^2, γ^2, e'^2, m' is seen in this table. Thus the term of order $m^4\gamma^2$, obtained by Delaunay, furnishes −0″·3705. The line "Est. Rem." is the estimated sum of the remaining terms of Delaunay's expressions. The next line gives the resulting value which is thus obtained, and in the last line are the correct values resulting from my calculations. When the possible errors of estimation are taken into account, the agreement is fairly satisfactory, except in the case of the terms depending upon e^2.

The results of the calculations for these latter are given in my paper 'On the Elliptic Inequalities in the Lunar Theory.' § Feeling that the discordance was too great to rest on a single determination, I recalculated the whole of the inequalities depending on e^2 by my later method. ‖ An almost exact agreement with the earlier result was found, showing that certainly Delaunay's coefficient for e^2m^7, and perhaps that for e^2m^6, are

* *Acta. Math.* vol. viii. pp. 1–36. *Annals of Math.* vol. ix. pp. 31–41.

† *Ann. de la Fac. des Sc. de Toulouse*, vol. vi.

‡ *C. R.* vol. lxxiv. pp. 19 *et sq.*, where these and the following results will be found.

§ *Amer. Jour. Math.* vol. xv. pp. 244–263, 321–338.

‖ *Ibid.* vol. xvii. pp. 318–358.

seriously wrong. It will be noticed that the small estimated remainder has the positive sign, whereas the true value shows that it should be a comparatively large quantity with the negative sign.

9. *Terms of the Fourth Order.*—The values of these must be obtained from Delaunay's expressions. The manner in which his method is carried out, taken in conjunction with the tests considered in § 6, give us a reasonable assurance of their accuracy; doubt only arises from the estimated remainders.

Daily Motions.

Factors.	e^4	γ^4	e'^4	a^2/a'^2
	"	"	"	"
m^2	−0·0002	−0·0121	+0·0000	+0·0024
m^3	...	+0·0056	...	+0·0019
Est. Rem.	−0·0004	+0·0040	+0·0001	+0·0020
Delaunay	−0·0006	−0·0025	+0·0001	+0·0063

Daily Motions.

Factors.	γ^2e^2	$\gamma^2e'^2$	$e^2e'^2$
	"	"	"
m^2	+0·0139	−0·0013	−0·0001
m^3	+0·0003	−0·0010	−0·0006
Est. Rem.	−0·0020	−0·0010	−0·0010
Delaunay	+0·0122	−0·0033	−0·0017

The sum of these gives

Daily Motion, +0″·0105,

with a possible error* due to wrong estimation of ± 0″·005. It will be noticed that the error arises chiefly from the terms which contain γ^4, γ^2e^2, a^2/a'^2 as factors.

Annual Motion of the Perigee.

10. Gathering together the true values given in §§ 7, 8, and the result obtained in § 9, we multiply them by 365·25 to reduce them to annual motions in a Julian year. The portions due to the figure of the Earth and to planetary action must also be included. The following are the results, with the authorities for them.

* No technical sense is to be attached to this expression.

Annual Motions.

Terms of the form $nf(m)$	+ 148 525″3	(Hill)
„ „ „ $ne^2f(m)$	− 519·3	(Brown)
„ „ „ $n\gamma^2f(m)$	− 1 739·6	„
„ „ „ $ne'^2f(m)$	+ 156·2	„
„ „ higher orders	+ 3·8 ± 1″8	(Delaunay)
From the solar action	+ 146 426·4 ± 1·8	
Figure of the Earth	+ 6·8	(Hill)*
Planetary action	+ 2″·1	(Hansen)†
From theory	+ 146 435·3 ± 1·8	. . . . . (i)
From observation	+ 146 435·6	(Hansen)† . . (ii)
From Hansen's theory	+ 146 434·0	„ . . . (iii)

Hansen, however, has obtained for the inequalities depending on the figure of the Earth the value 5″·9. Accepting the value obtained in the very extended and accurate investigation made by Dr. Hill, we must add + 0″·9 to Hansen's result, making it

+ 146 434″·9. . . . . (iv)

The evidence of agreement with observation afforded by the comparison of the values (i), (ii), is unfortunately rendered useless by the large possible error of ± 1″·8, which I have felt compelled to assign to the estimations of the higher terms due to the solar action. Hansen's determination of the part due to planetary action is probably correct within two or three tenths of a second.

If Hansen's result for the solar part be correct and we accept the value (iv), which at this stage is the best theoretical determination, it would seem that the hypothesis considered by Professor Newcomb is hardly verified in the case of the Moon. The required difference is 1″·4, while that furnished by the values (ii) and (iv) above is only 0″·7. The question must remain unanswered until an exact determination of the solar inequalities has been made. Such a determination is now in progress, and I hope may be finished before the lapse of any very considerable time, seeing that the outstanding parts, which are the chief cause of the possible error, are those easiest to calculate.

Motion of the Node.

11. *Term of Zero Order.*—This has been calculated to a high degree of accuracy by Professor J. C. Adams ‡ and Mr. P. H.

* Papers published for the Amer. Eph. vol. iii. p. 344.

† Hansen's results given here and in § 14, are found in Arts. 103, 159, 174 of the *Darlegung*.

‡ *M.N.R.A.S.* vol. xxxviii. pp. 43–49.

Cowell.* The agreement with Delaunay's result is quite satisfactory. From the value of the latter there results

Daily Motion, $-189''\cdot7005$.

12. *Terms of the Second Order.*—The results are exhibited in the same way as in § 8. The portion depending on γ^2 is extracted from Mr. Cowell's paper just referred to; those depending on e^2, e'^2, are the results of my calculations.

Daily Motions.

Factors.	e^2	γ^2	e'^2
m^2	$-1''\cdot1999$	$+0''\cdot8021$	$-0''\cdot0840$
m^3	$-0\cdot3534$	$-\cdot0675$	$+\cdot0040$
m^4	$-\cdot0958$	$-\cdot0197$	$+\cdot0053$
m^5	$-\cdot0270$	$-\cdot0016$	$+\cdot0022$
Sum	$-1\cdot6761$	$+0\cdot7133$	$-0\cdot0725$
Est. Rem.	$-\cdot010$	$+\cdot000$	$+\cdot0009$
Delaunay	$-1\cdot686$	$+0\cdot713$	$-0\cdot072$
True value	$-1\cdot6865$	$+0\cdot7134$	$-0\cdot0697$

The agreement in all cases is sufficiently close. †

13. *Terms of the Fourth Order.*—As in the case of the perigee, we obtain these from Delaunay's expressions.

Daily Motions.

Factors.	e^4	γ^4	e'^4	a^2/a'^2
m^2	$+0''\cdot0008$	[none]	$-''\cdot0000$	$-''\cdot0024$
m^3	$-\cdot0005$	$+\cdot0001$	...	$-\cdot0005$
Est. Rem.	$-\cdot0003$	...	...	$-\cdot0001$
Delaunay	$+\cdot0000$	$+\cdot0001$	$-\cdot0000$	$-\cdot0030$

Daily Motions.

Factors.	$\gamma^2 e^2$	$\gamma^2 e'^2$	$e^2 e'^2$
m^2	$-''\cdot0103$	$+''\cdot0003$	$-''\cdot0005$
m^3	$+\cdot0043$	$-\cdot0001$	$-\cdot0004$
Est. Rem.	$+\cdot0030$	$-\cdot0002$	$-\cdot0004$
Delaunay	$-\cdot0030$	$+\cdot0000$	$-\cdot0013$

The sum of these gives

Daily Motion $-0''\cdot007$,

with a possible error due to wrong estimation of $\pm''\cdot003$. Nearly the whole of this latter quantity arises in the estimation of the terms depending on $\gamma^2 e^2$.

* *Amer. Jour. Math.* vol. xviii. pp. 59–127.

† See the Postscript to this paper.

Annual Motion of the Node.

14. Proceeding as before, we find the following :—

Terms of the form $nf(m)$	$-69\ 288''.1$	(Adams & Cowell)
„ „ „ $ne^2f(m)$	$-\ 616.0$	(Brown)
„ „ „ $n\gamma^2f(m)$	$+\ 260.6$	(Cowell)
„ „ „ $ne'^2f(m)$	$-\ 25.5$	(Brown)
„ „ higher orders	$-\ 2.6 \pm 1''.1$	(Delaunay)
From solar action	$-69\ 671.6 \pm 1.1$	
From the figure of the Earth	$-\ 6.4$	(Hill)
From planetary action	$-\ 1.5$	(Hansen)
From theory †	$-69\ 679.5 \pm 1.1$	. . . . . (i)
From observation	$-69\ 679.5$	(Newcomb)* . . . (ii)
From Hansen's theory	$-69\ 676.8$	. . . . . (iii)

Hansen obtains for the inequality arising from the figure of the Earth the value $-5''.9$. Accepting Dr. Hill's value, we find for Hansen's theoretical value

$$-69\ 677.3 \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (iv)$$

The close agreement between the results (i) which I have deduced from theory and (ii) deduced from observation must be considered in connection with the possible error $\pm 1''.1$. The corrected result of Hansen (iv) still differs from that given by observation by $2''.2$. It appears, then, that the new theoretical value is rather more accurate than that of Hansen. It is probable that when the remainder of the solar inequalities in the motion of the node have been determined, an almost perfect agreement will be found between theory and observation.

15. While this determination is in progress, it would seem from the above discussion that the most accurate theoretical values as yet obtained are the result (iv) in the case of the perigee and the result (i) in the case of the node; that is to say,

Annual Mean Motion of the Perigee	$+146\ 434''.9$,
Annual Mean Motion of the Node	$-\ 69\ 679''.5$,

the amount by which these values may differ from the correct

* This value was kindly communicated to me by Professor Newcomb. It differs from Hansen's value by $0''.1$.

† This result was announced at the December meeting of the American Mathematical Society.

theoretical values being not more than $\frac{1}{70,000}$ part of the whole in each case.

Haverford College, Pa.:
1897 *January* 5.

Postscript.—In the course of obtaining a verification of Delaunay's expressions for the secular accelerations, an error in the *Théorie* was discovered in the following way. The value of the part of the motion of the node which depends on e'^2, as given by Delaunay, is

$$-ne'^2\left(\frac{9}{8}m^2-\frac{23}{32}m^3-\frac{3261}{256}m^4-\frac{73423}{1024}m^5\right).$$

This value failed to furnish correctly the terms in the secular acceleration of the node which have the factors m^3, m^5, and, in that of the mean motion, the factors $m^3\gamma^2$, $m^5\gamma^2$. At first the natural assumption was that these four terms were wrong; but, on reconsidering Delaunay's method of obtaining them, this did not seem probable. I found that *all* the terms could be made to agree if we had

$$-ne'^2\left(\frac{9}{8}m^2-\frac{33}{32}m^3-\frac{3261}{256}m^4-\frac{73413}{1024}m^5\right)$$

instead of the above expression.

On referring to de Pontécoulant, *Système du Monde*, vol. iv. p. 567, I found that he gave 33 instead of 23 as the numerator of the second term. Moreover, the small difference between my result and that of Delaunay, as shown in the last column of the table in § 12 above, is exactly accounted for when the change is made.

It then seemed worth while to see if an error in Delaunay's *Théorie* could be detected without much trouble, and it was almost immediately found to be a simple error of transcription. The term

$$m'\frac{a^2}{a'^3}\left\{\ldots\left(\ldots+\frac{33}{16}\gamma^2e'^2\ldots\right)\frac{n'}{n}\ldots\right\},$$

in the value of the constant part of R on p. 2 of vol. ii. is incorrectly transcribed

$$m'\frac{a^2}{a'^3}\left\{\ldots\left(\ldots+\frac{23}{16}\gamma^2e'^2\ldots\right)\frac{n'}{n}\ldots\right\},$$

in the more extended value on p. 234, and the error is retained in the values of $\frac{dl}{dt}$, $\frac{dg}{dt}$, $\frac{dh}{dt}$, which immediately follow. This accounts for the error in the second term of the expression given above, and doubtless for that in the fourth term also.

On the Theoretical Values of the Secular Accelerations in the Lunar Theory. By Ernest W. Brown.

(*Abstract.*)

The accurate determination of certain inequalities in the Moon's motion has made it possible to find the theoretical values of the secular accelerations with a high degree of accuracy. The method of determination consists in using the theorem of Professor Newcomb for finding the secular accelerations in combination with that of the author connecting the mean motions of the perigee and node with the constant part of the lunar parallax. The resulting values, with the greatest possible amounts by which they are uncertain (assuming Newcomb's value for $\delta e'$ to be correct), are :

Secular accelerations per century of the

Mean motion	+ 5″·91	± 0″·02,
Perigee	−38·9	± 0·1,
Node	+ 6·56	± 0·02.

1. The theoretical determination of the secular accelerations, formerly one of the most difficult and tedious problems in the lunar theory, has been rendered quite simple by the researches of Professor Newcomb.* Until the publication of these, two years ago, the only investigation with any approach to high accuracy was that of Delaunay, who carried the approximations so far as to include a great number of terms. The enormous labour of finding these, however, was hardly compensated by the result obtained, owing to the uncertainty produced by the slow convergence of the series when arranged according to powers of m. Hansen's results are entirely numerical, and he used those furnished by observation in the construction of his tables. In Newcomb's memoir, just referred to, the values are deduced from Delaunay's algebraical expressions as obtained in the *Théorie de la Lune*, but these again suffer from slow convergence, and errors must occur, first, from incorrect estimations of the remainders, and, secondly, from errors in Delaunay's theory. Owing to the former cause, Professor Newcomb concludes that his value (5″·60) for the secular acceleration of the mean motion is uncertain by more than $\frac{1}{20}$ of the whole. He adds (mem. cit. p. 199) : "Although all the observations hitherto made on the Moon would not enable us to detect errors of this magnitude, a more accurate determination would be desirable from a theoretical point of view." It is the

* Papers published for the use of the *Amer. Eph.* vol. v. pt. iii.

object of this paper to show how such a determination may be made, and to find the values correctly to $\frac{1}{300}$ part of the whole in each case.

This has been rendered possible in three ways: First, by Newcomb's theorem, showing how Delaunay's final constants L, G, H may be calculated from the expressions for the rectangular coordinates of the Moon; secondly, by my theorem connecting the constant term in the expression for the parallax with L, G, H and the motions of the perigee and node;* and, thirdly, by the new determinations of these mean motions, the results of which have been given in my paper "On the Mean Motions of the Lunar Perigee and Node."† These theorems have also been employed to test Delaunay's algebraical expressions for the secular accelerations, and the results are given in § 4 below. In order to find the numerical values, such expressions as $\frac{\partial^2 \pi}{\partial n \partial . e'^2}$ have to be calculated; it is shown in § 5 how they may be found with very fair accuracy when the complete numerical value of $\frac{\partial \pi}{\partial e'^2}$ and only a few terms of its slowly convergent algebraical expression are known. Finally, the numerical results are given, with the amounts by which they are uncertain.

General Formulæ for the Secular Accelerations.

2. Professor Newcomb's theorem (mem. cit. p. 191) states that the variations of n (or a), e, γ due to a variation $\delta e'$ of e' may be obtained accurately to the first order, with respect to δ, by solving the equations

$$\delta L = 0, \quad \delta G = 0, \quad \delta H = 0,$$

or

$$\frac{\partial L}{\partial n}\delta n + \frac{\partial L}{\partial . e^2}\delta . e^2 + \frac{\partial L}{\partial . \gamma^2}\delta . \gamma^2 = -\frac{\partial L}{\partial . e'^2}\delta . e'^2, \text{ \&c.};$$

and that the secular accelerations of the mean motion, the perigee and node, are then given by

$$\delta\epsilon = \int \delta n \, dt, \quad \delta\varpi = \int \delta\varpi_1 \, dt, \quad \delta\theta = \int \delta\theta_1 \, dt,$$

where ϖ_1, θ_1 are the mean motions of the perigee and node. Putting $L = c_1$, $G - L = c_2$, $H - G = c_3$, the first three equations become

$$\delta c_1 = 0, \quad \delta c_2 = 0, \quad \delta c_3 = 0.$$

* *Proc. London Math. Soc.* 1897.
† *Monthly Notices R.A.S.* 1897.

I have shown in the latter of the two papers just referred to that the variations of n, e, γ, e' also satisfy the equations

$$c_2\,\delta\cdot\frac{\partial\pi_1}{\partial n}+c_3\,\delta\cdot\frac{\partial\theta_1}{\partial n}=\frac{3}{2}(\mathrm{E}+\mathrm{M})\,\delta\cdot\frac{\partial}{\partial n}\left(\frac{1}{r}\right)_0,$$

$$c_2\,\delta\cdot\frac{\partial\pi_1}{\partial\cdot e^2}+c_3\,\delta\cdot\frac{\partial\theta_1}{\partial\cdot e^2}=\frac{3}{2}(\mathrm{E}+\mathrm{M})\,\delta\cdot\frac{\partial}{\partial\cdot e^2}\left(\frac{1}{r}\right)_0,$$

$$c_2\,\delta\cdot\frac{\partial\pi_1}{\partial\cdot\gamma^2}+c_3\,\delta\cdot\frac{\partial\theta_1}{\partial\cdot\gamma^2}=\frac{3}{2}(\mathrm{E}+\mathrm{M})\,\delta\cdot\frac{\partial}{\partial\cdot\gamma^2}\left(\frac{1}{r}\right)_0.$$

These results immediately follow from those given in my former paper in the *Monthly Notices* by submitting them to a variation δ and putting δc_1, δc_2, δc_3 zero. As before, $\mathrm{E}+\mathrm{M}=n^2a^3$, and $\left(\frac{1}{r}\right)_0$ denotes the constant term in the expression of $\frac{1}{r}$; the constants are defined as in Delaunay's final expressions for the coordinates. The square of the ratio of the solar to the lunar parallax is neglected, but its effect is quite insensible.

The first of these three equations may be used effectively to find the secular accelerations. We have

$$\delta\cdot\frac{\partial\pi_1}{\partial n}=\frac{\partial^2\pi_1}{\partial n^2}\,\delta n+\frac{\partial^2\pi_1}{\partial n\,\partial\cdot e'^2}\,\delta\cdot e'^2+\frac{\partial^2\pi_1}{\partial n\,\partial\cdot e^2}\,\delta\cdot e^2+\frac{\partial^2\pi_1}{\partial n\,\partial\cdot\gamma^2}\,\delta\cdot\gamma^2,$$

with similar results for the other expressions. It can be easily shown that c_2, $\delta\cdot e^2$ contain the factor e^2 in all their terms, and c_3, $\delta\cdot\gamma^2$ the factor γ^2. Also it is known by a theorem of Adams* that there are no terms in $\left(\frac{1}{r}\right)_0$ of the form $\frac{1}{a}e^2 f(m,e'^2)$, $\frac{1}{a}\gamma^2 f(m,e'^2)$. Hence, in order to find δn to the orders e^2, γ^2, and all powers of e'^2, we can neglect $\delta\cdot e^2$, $\delta\cdot\gamma^2$ in the first equation, so that it becomes

$$c_2\left(\frac{\partial^2\pi_1}{\partial n^2}\,\delta n+\frac{\partial^2\pi_1}{\partial n\,\partial\cdot e'^2}\,\delta\cdot e'^2\right)+c_3\left(\frac{\partial^2\theta_1}{\partial n^2}\,\delta n+\frac{\partial^2\theta_1}{\partial n\,\partial\cdot e'^2}\,\delta\cdot e'^2\right)$$

$$=\frac{3}{2}(\mathrm{E}+\mathrm{M})\left[\frac{\partial^2\mathrm{P}_0}{\partial n^2}\,\delta n+\frac{\partial^2\mathrm{P}_0}{\partial n\,\partial\cdot e'^2}\,\delta e'^2\right],$$

where P_0 has been put for $\left(\frac{1}{r}\right)_0$.

If we neglect e^2, γ^2, it is seen that the principal part of δn is given by

$$\frac{\partial^2\mathrm{P}_0}{\partial n^2}\,\delta n=-\frac{\partial^2\mathrm{P}_0}{\partial n\,\partial\cdot e'^2}\,\delta e'^2\quad\ldots\ldots\quad(1)$$

* *Monthly Notices*, vol. xxxviii. pp. 460-472. *Coll. Works*, vol. i. pp. 189-204.

When the principal part of δn has been found from this equation, its value may be substituted in the left-hand member of the previous equation, and the parts depending on e^2, γ^2 can then be evaluated.

For the motion of the perigee we have

$$\delta\pi_1 = \frac{\partial\pi_1}{\partial . e'^2}\delta . e'^2 + \frac{\partial\pi_1}{\partial n}\delta n + \frac{\partial\pi_1}{\partial . e^2}\delta . e^2 + \frac{\partial\pi_1}{\partial . \gamma^2}\delta . \gamma^2.$$

If we neglect e^2, γ^2, it will be sufficient to use the first two terms only. The parts of chief importance in all cases arise from $\partial\pi_1/\partial . e'^2$, and their accuracy depends mainly on the accuracy with which the terms having the factor e'^2 in π_1 are known. If, however, the parts in $\delta\pi_1$, depending on e^2, γ^2, be required, it will be simplest to find $\delta . e^2$, $\delta . \gamma^2$ from the equations $\delta c_2 = 0$, $\delta c_3 = 0$, respectively. The principal parts of $\delta . e^2$, $\delta . \gamma^2$ are by this method found in the forms

$$n\delta . e^2 = e^2 f(m)\delta n, \qquad n\delta . \gamma^2 = \gamma^2 f(m)\delta n,$$

and can therefore be found, since the value of δn is already known.

In the present state of the lunar theory nothing is to be gained by calculating these higher portions in the case of the perigee, for the complete numerical values of the terms in π_1, which have the factors $e^2e'^2$, $\gamma^2e'^2$ have not yet been obtained, and Adams' value of P_0 furnishes only the terms up to the orders $e^2e'^2m^3$, $\gamma^2e'^2m^3$. Hence we must verify Delaunay's values to this order and estimate for the remainders. Fortunately, owing to the smallness of the quantities involved, the possible errors of estimation are very small and can be easily seen.

Exactly similar results hold for $\delta\theta_1$.

3. The equation (1) explains partly the slowness of the convergence of the expression which represents the principal part of δn when expanded in powers of m. All inequalities in the lunar theory which contain the factor e' appear to be more or less slowly convergent. When such expressions as $e'^2 f(m)$ are differentiated with respect to n, the earlier terms will converge more slowly still, but the convergence of the later terms will not be much affected. The calculations further show that slow convergence in the higher terms will arise partly from the expansion of the inverse of $\frac{\partial^2 P_0}{\partial n^2}$ in powers of m; a remedy for this is evident. The convergence of all the results is, as usual, improved by using $m_1 = n'/(n-n')$ instead of $m = n'/n$ as a parameter.

4. *A Test of Delaunay's Expressions for the Secular Accelerations.*—These are given in *C.R.* vol. xliv. p. 209, in terms of Plana's constants, and, with an increased number of terms, in *C.R.* vol. lxxiv. p. 174, in terms of his own constants. The constant part

of $1/r$ has been obtained by Adams (*Coll. Works*, vol. i. p. 203), and his value was used in the formulæ of § 2. The values of c_2, c_3 are given by Newcomb (mem. cit. p. 184), and the values of π_1, θ_1 are those of Delaunay (*C.R.* vol. lxxiv. p. 19) with the corrections noted in my paper in the *Monthly Notices* already referred to (§ 1). The last powers of m tested in each case are as follows :—

The value of $\delta\epsilon$ was tested as far as m^7, γ^2m^5, e^2m^5, e'^2m^5, and the values of $\delta\pi$, $\delta\theta$ as far as m^5, γ^2m^3, e^2m^3, e'^2m^2. The only differences found were the coefficients of the terms involving γ^2m^3 in $\delta\pi$ and e^2m^3 in $\delta\theta$, for which $-\frac{694}{4}$, $-\frac{694}{16}$ were found instead of $-\frac{693}{4}$, $-\frac{693}{16}$. The terms involving a^2/a'^2 and higher powers and products of e^2, γ^2, e'^2 do not produce additions so great as $0''{\cdot}01$, and they will therefore not be considered.

5. *Method of combining algebraical and numerical results to obtain the derivatives with regard to* n.—The problem may be stated as follows : Given the first i terms and also the complete numerical value of a series whose terms are diminishing in absolute value, to find a close approximation to the value of its derivative. The following is a practical method of solution :—

Let

$$f(m) = a_0 + a_1 m + a_2 m^2 + \ldots,$$

where a_0, a_1, . . are numerical coefficients, and put

$$f_i(m) = a_0 + a_1 m + a_2 m^2 + \ldots + a_{i-1} m^{i-1}.$$

Taking the derivatives with regard to m, we can write the result

$$mf'(m) = mf_i'(m) + i\left[a_i m^i + \frac{i+1}{i} a_{i+1} m^{i+1} + \ldots\right].$$

If i be not too small (*e.g.* not less than 5), and the terms of the series are not diminishing too slowly (*e.g.* with a ratio not much greater than $\frac{1}{2}$), the error committed by putting

$$mf'(m) = mf_i'(m) + i[mf(m) - mf_i(m)]$$

will be small compared with the true value of $mf'(m)$. We shall generally obtain greater accuracy by using $i+$ a proper fraction instead of i as the factor, when the series appears to be diminishing with fair regularity.

For example, the part of π_1 which depends on e'^2 when the parameter m_1 is used, is

$$ne'^2\left(\frac{9}{8}m_1^2 + \frac{753}{32}m_1^3 + \frac{42243}{256}m_1^4 + \frac{942777}{1024}m_1^5\right).$$

Here $i=6$, and reducing the portion in brackets to numbers, we obtain

$$f_6(m_1) = +\cdot00735 + \cdot01244 + \cdot00705 + \cdot00318 = +\cdot03002.$$

I find

$$f(m_1) = +\cdot032063.$$

Hence

$$f(m_1) - f_6(m_1) = +\cdot00204.$$

Applying the formula, and using $6\frac{1}{2}$ as the multiplying factor of this difference, we find

$$f'(m_1) = +\cdot0147 + \cdot0373 + \cdot0282 + \cdot0159 + \cdot0133 = +\cdot1094.$$

The result might possibly be as much as four or five units wrong in the last place of decimals, but in all the cases treated below, the possible error does not affect the results to the degree of accuracy required. To complete the determination, we have, for this portion of π_1,

$$\frac{\partial \pi_1}{\partial n} = f(m_1) - (1 + m_1) m_1 f'(m_1)$$
$$= +\cdot0321 - \cdot1182 = -\cdot086,$$

which is not more than one unit wrong in the third place of decimals.

The Numerical Values.

6. The following are the numerical data required :—

In the values of c_2, c_3, we only require the terms which are of the forms $na^2e^2f(m)$, $na^2\gamma^2f(m)$, respectively. These may be accurately obtained by Newcomb's method from the expressions in terms of rectangular coordinates, c_3 from the results in a paper by Mr. P. H. Cowell,* and c_2 from those in a paper by the writer.† We find

$$c_2 = -\cdot474035na^2e^2, \qquad c_3 = -2\cdot00257na^2\gamma^2.$$

The values of π_1, θ_1 are as follows :‡

$$\pi_1 = n[+\cdot0085726 + \cdot032063e'^2],$$
$$\theta_1 = n[-\cdot039992 - \cdot005224e'^2].$$

Proceeding as in § 5, we then find

$$\frac{\partial \pi_1}{\partial n} = -\cdot01502 - \cdot086e'^2,$$

$$\frac{\partial \theta_1}{\partial n} = +\cdot03708 + \cdot00319e'^2,$$

$$n\frac{\partial^2 \pi_1}{\partial n^2} = -\cdot0489, \qquad n\frac{\partial^2 \theta_1}{\partial n^2} = -\cdot00661.$$

* *Amer. Jour. Math.* vol. xviii. p. 113.

† *Ibid.* vol. xv. p. 261.

‡ See the paper "On the Mean Motions of the Lunar Perigee and Node."

The numbers contain powers of m only; the omitted portions, depending on e^2, etc., are not required.

Further, from Adams' algebraical results and my numerical calculations:

$$aP_0 = 1{\cdot}00091 + {\cdot}0011750e'^2 + {\cdot}00064e'^4,$$

$$an\frac{\partial P_0}{\partial n} = +{\cdot}66551 - {\cdot}0009865e'^2 + {\cdot}0026e'^4,$$

$$an^2\frac{\partial P_0}{\partial n^2} = -{\cdot}21975 - {\cdot}0001315e'^2.$$

7. Pursuing the operations of § 2 above, we obtain

$$\delta n = [-{\cdot}004489 + {\cdot}024e'^2 + {\cdot}1235e^2 - {\cdot}0196\gamma^2]n\delta \cdot e'^2,$$

$$\delta\pi_1 = +{\cdot}03213n\delta \cdot e'^2,$$

$$\delta\theta_1 = -{\cdot}005241n\delta \cdot e'^2.$$

Put now, with Delaunay,

$$\int n\delta e'^2 dt = -1270''T^2,$$

where T is the time reckoned in centuries of Julian years, and include the parts of $\delta\pi_1$, $\delta\theta_1$ which depend on e^2, γ^2, e'^2 from his expressions (see § 4 above), estimating for the remainders in each case. The maximum possible error due to the latter is appended, with the resulting values in the table:

Secular Accelerations.

Parts of form.	In δn.	In $\delta\pi_1$.	In $\delta\theta_1$.
$f(m)$	$+5''{\cdot}70$	$-40''{\cdot}8$	$+6''{\cdot}66$
$e'^2 f(m)$	$-0{\cdot}01$	$+0{\cdot}0$	$-0{\cdot}00$
$e^2 f(m)$	$+0{\cdot}47$	$+0{\cdot}2$	$+0{\cdot}14$
$\gamma^2 f(m)$	$-0{\cdot}05$	$+0{\cdot}4$	$-0{\cdot}02$
Complete values	$+6{\cdot}11 \pm 0''{\cdot}02$	$-40{\cdot}2 \pm 0''{\cdot}1$	$+6{\cdot}78 \pm 0''{\cdot}02$

These results agree almost exactly with those of Delaunay. With the latest values for the masses of the planets, Professor Newcomb finds (mem. cit. p. 199),

$$\int n\delta e'^2 = -1229''T^2.$$

Hence the definitive theoretical values of the secular accelerations per century are, for

The Mean Motion	...	...	...	$+5''{\cdot}91 \pm 0''{\cdot}02$;
The Perigee	...	...	...	...	$-38{\cdot}9 \pm 0{\cdot}1$;
The Node	...	...	...	...	$+6{\cdot}56 \pm 0{\cdot}02$.

Laying aside the question of the accuracy of the value of $\int n\delta\epsilon'^2$, the above theoretical values for the secular acceleration are correct to $\frac{1}{300}$ part of the whole in each case.

Haverford College, Pa.:
1897 January 11.

On a Photographic Transit Circle. By H. H. Turner, M.A., B.Sc., Savilian Professor.

1. The desirability of introducing photography into meridian observations, as a method of eliminating personal and other errors, has been recognised by many astronomers, and will probably be admitted by all, if this introduction can be accomplished without endangering the simplicity and stability of the present form of instrument. The following solution of this problem, which presents some advantages not realised in other forms, is offered for consideration.

2. It may be well in the first instance to enumerate the chief features of the present instrument—its advantages and disadvantages.

Features:

(*a*) Movable visual telescope with two micrometers at right angles.

(*b*) Two carefully made pivots, allowing one degree of freedom only.

(*c*) Graduated circle and microscopes.

(*d*) Chronograph.

All these, or their equivalents, may thus be allowed in any new arrangement.

Advantages:

(*e*) Stability, owing to there being only one degree of freedom, excepting in so far as the micrometers are used.

(*f*) Simplicity.

The advantages may generally be brought under one or other of these heads. It is unnecessary to specify them in detail unless we are going to propose any rearrangement of the instrument which will sacrifice any of them, and that is not my present purpose. It is more important to consider carefully how we may remove the

Disadvantages of the Present Instrument, viz.:

(*g*) Personal equation of all kinds.

(*h*) Flexure and irregular refraction.

(*i*) Limitation to comparatively bright stars.

3. Considering first (*g*), personal equation, photography is clearly useful here. In measuring a photograph different persons usually have a small 'error of bisection,' but this can be eliminated at leisure by turning the photograph round and remeasuring it, and a successful photographic method would thus be of the greatest advantage, not only in longitude work, where the absolute time is required, but in forming star catalogues, which are at present affected with the personality dependent on brightness of the star.

4. With regard to (*h*) I have already proposed (*Monthly Notices*, vol. liv. p. 412) an arrangement of a fixed telescope pointing to a plane mirror. The mirror can be made thick enough to be free from flexure without being nearly so heavy as a large telescope, and if carefully mounted in the meridian, in the same way as a transit is mounted, nothing would be lost of stability and very little of simplicity. The graduated circle (or equivalent) would now be attached to the mirror. It was further pointed out in the paper above cited that the effects of irregular refraction from the atmosphere of the observing room (small and much over-rated, as I believe these to be, see *Mem. R.A.S.* vol. li. pp. 110–116 and *Monthly Notices*, vol. liv. p. 488) are minimised by this arrangement, for the mirror may be placed practically in the open air at a distance from the observer, so that the light of a star travels as far as the mirror without much disturbance from irregular strata of air. On their way from the mirror to the observer the rays of light may suffer such disturbance, but this will be the same for all stars, whatever the zenith distance, and hence will go out in the zenith point.

5. With regard to (*i*), it is true that observations of stars and small planets to about the 10th magnitude are found possible at (*e.g.*) the Royal Observatory, Greenwich, with the transit circle of 8-inch aperture. But even then, for the fainter objects, illuminated wires must be used instead of the illuminated field, and the observations are found to lose in accuracy. With smaller instruments the range of available stars is more restricted, and it will not be possible for us at Oxford (with the Barclay transit circle of 4 in. aperture, and with no apparatus for illuminating the wires) to reobserve the great majority of the faint stars of the *Cambridge Catalogue* (1875·0), which we are using as reference stars for the work of the *Astrographic Catalogue*.

But one of the chief uses of photography is to bring faint objects within easier reach, and if we can use a fairly long exposure (of some minutes, say) there is no reason why an instrument of moderate power should not photograph stars to the 9th or 10th magnitude. We see at once, however, that to use photographic trails will not do; we are just as much restricted as before to bright stars. Something must move to follow the star, and that cannot be the telescope which we have already fixed, nor the mirror which is to have only one degree of freedom. Hence it must be the photographic plate. As the star travels

across the field of the fixed telescope, which we may assume about 2° in breadth, the plate must be moved so that the star falls continuously on one spot, which thus receives an exposure of 8 minutes at the equator. This should be sufficient to photograph tolerably faint stars with a good photographic lens of modest dimensions. In any case, those observatories which possess instruments for the work of the Astrographic Chart would be able at some time to remove the object glass in its cell and mount it in a wooden tube, which would be all that is necessary in the case of a fixed telescope; and then an exposure of 8 minutes at the focus would give 11th or 12th magnitude stars.

6. Now it looks at first sight as though moving the plate were just as bad as moving the telescope or the mirror, were, in fact, giving up the idea of having only one degree of freedom. But by a simple device we can entirely obviate this objection. The plate need not be fixed to the telescope; all that is necessary is that *the position of the plate with reference to the fixed telescope at any instant should be recorded.* Suppose a spot of light from a fixed source to shine on the plate every second, the interruptions being made by the standard clock. As the plate travels across the field a series of dots will be formed which will show the irregularities of the motion. If there be two spots (one at the top and one at the bottom, say) we shall know the orientation of the plate as well as its position in the slide at any instant, and if the motion be tolerably uniform, such as can be secured by any one of a number of mechanical devices, the position of any star photographed can be referred to the mean of these seconds' spots on the plate. The process will be rather like referring a star to the several wires of the transit reticule, in fact the moving plate is now our chronograph, so that we are not really adding anything to the "features" specified in § 2. In the case of bright stars, the exposure would only be a few seconds, and the measures of the spots could be quickly made. In the case of longer exposures, of 8 minutes, say, it would probably not be necessary to measure the whole $8 \times 60 = 480$ spots; if every 10th or even 30th were measured, enough information would probably be obtained as to the regularity of the clock driving to show whether it was necessary to proceed further.

7. Before entering further into the details of the arrangement let us now sum up the features of the new instrument, and compare them with the ordinary transit circle. The following is a brief tabular comparison of this kind :—

Ordinary Transit Circle.	*Proposed Photographic Transit Circle.*
(*a*) Movable visual telescope with two micrometers at right angles.	(*a*) Fixed photographic telescope. The micrometers are not attached to the telescope, but are used to measure the photographic plate.

(*b*) Two carefully made pivots, allowing one degree of freedom only.	(*b*) The pivots attached to a plane mirror, which has thus one degree of freedom only.
(*c*) Graduated circle and microscopes.	(*c*) Retained, in connection with the mirror.
(*d*) Chronograph.	(*d*) A corresponding arrangement moves and records position of the photographic plate.
(*e*) Stability.	(*e*) Retained as in (*b*).
(*f*) Simplicity.	(*f*) The only additional apparatus is the plane mirror.
(*g*) Personal equation affects the observations.	(*g*) Personal equation minimised or eliminated.
(*h*) Flexure and irregular refraction.	(*h*) The flexure of a comparatively small mirror substituted for that of a long tube held by the middle. Effects of irregular refraction minimised, the mirror being in the open.
(*i*) Limitation to bright stars.	(*i*) Stars of 10th magnitude or fainter within reach.

8. This theoretical comparison seems to promise well, and I see no reason why it should break down in practice. There are, of course, numerous small points of detail to be worked out, but none of them present any great difficulties. Most of them, though perhaps not all, are considered in the following paragraphs. I am proceeding with the mounting of an instrument at the University Observatory, and a fuller account will be given after practical experience of the working.

9. *Movement of the Plate.*—So long as the driving is regular it is not necessary that it be *exactly* of the stellar rate unless we want a very faint star. If the stellar rate and the plate rate differ the star will trail slightly, but we shall make no sensible error in referring the middle of the trail to the mean of the seconds' marks.

10. Now stars of different declinations travel at different rates; hence we must have some contrivance for adjusting the rate at which the plate travels. Various devices might be used. There is an ingenious one already in use at Greenwich for the personal equation machine (*Monthly Notices*, vol. xlviii. p. 3); but perhaps the simplest would be to have a long graduated arm, pivoted at one end, the other moved by the clock; a string attached to the plate holder and passing over a fixed pulley (so that the pull on the plate is always in the same direction) could be attached to this arm at any distance from the pivot, and would thus pull the plate along at a suitable rate. But the details are still to be worked out.

11. *The Variable Chronographic Scale.*—For stars near the Pole the seconds' marks would be close together, while for

equatorial stars they would be better separated. The chronograph scale is thus wider for the latter than the former, and given errors of measurement affect the time of transit less in the ratio of the secant of declination. But it is easily seen that the error of transit in arc of a great circle is the same for all stars. There is, however, another inconvenience in a close scale, viz. that the spots would interfere with one another. This must be obviated by cutting out some of them. For instance, the observer might by hand hold down the electro-magnet or relay, &c. which admits the light periodically, only allowing it to rise every fifth or tenth second, as the case may be.

12. *Rotation of Plate.*—Another point to be considered is the rotation of the field of view, and the differential motion for stars in the same field, for one great advantage of this form of instrument is the possibility of photographing (and reducing together) a number of stars on the same plate. There are various mechanical contrivances by which a proper amount of rotation as well as of translation could be given to the plate; for the present I describe the simplest merely. Suppose for a moment the instrument is to be devoted to the reobservation of the (faint) stars in zone $+25°$. The plates taken with it will be of two kinds.

(A) Those for adjustments, for which bright stars may be used, though of all declinations.

(B) Those in zone $+25°$, which are faint.

Now construct a wooden arc of such a radius that the plate-holder will move along it so as just to suit zone $+25°$, and determine very accurately the point of the driving-arm which suits this exact declination, so that we get nice round discs for the stars in this zone readily. For other stars let the plate move along the same arc, but alter the rate to suit the star, though perhaps a rough approximation will suffice. The stars will trail slightly, but the exposures can be short, and no sensible error will be introduced. Indeed, we need not perhaps alter the rate of motion for some of the bright stars, but simply allow them to trail. When zone $+25°$ has been well observed we can make another arc for zone $+26°$ or any other zone. But if it be required to take faint stars in different zones on the same night we must make some linkage or epicycloidal arrangement for moving the plate.

13. *The Fixed Spots of Light.*—With regard to the spot or spots of light which mark the plate, there are advantages in the following arrangement: Let there be a point-source of light in the plane of the photographic film, but just beyond the field, above or below; which sends rays through the objective of the telescope. When the mirror is nearly normal to the telescope axis it will reflect these rays back through the objective to a point on the film (supposed at rest), which will become a line if the mirror is rotated gently. This line (l_1) obviously furnishes an important adjustment; if it is perfectly straight, the plane of the mirror is parallel to the horizontal axis, and if the point-source lies in its prolongation, the telescope is perpendicular to

the mirror. Further, if a mercury trough be placed below the mirror, and the mirror turned into a suitable position, another point or line (l_2) will be obtained showing the level adjustment of the horizontal axis. Now let there be a small, *fixed* mirror nearly normal to the telescope axis, which constantly reflects *a portion* of the light from the point-source on to the plate, at a point (l_3). The reflection from this mirror is to be the chronograph index, and is to be suitably interrupted by the clock. The distances l_3–l_1 and l_3–l_2, which can be recorded and measured whenever necessary, will furnish the necessary constants for reduction of the observations for collimation, level, and index error. The small fixed mirror will necessarily come between the objective and the large mirror, and will thus block out a portion of the objective ; it should thus be as small as possible. In some cases a small circular patch of tin-foil, placed on the outer surface of the object glass, might serve the purpose. As already remarked, it will be better to have *two* point-sources of light, one above and one below, to check the orientation of the plate.

14. *Collimation of the Instrument.*—The method of determining this has been partly indicated in the last paragraph. There are three points to be considered :—

(α) The mirror must be placed parallel to its axis of rotation.

(β) We must determine where a plane through the centre of the objective perpendicular to the mirror axis cuts the plate.

(γ) We must determine the positions of the point-source and its reflected images with reference to the plane specified in (β).

As regards (α), we have always the expedient of reversing the mirror in its Ys, and comparing the images either of the spot of light or of a star.

As regards (β) and (γ), enough has been said in the last paragraph.

It may be remarked that the *correction* for collimation error with this instrument need not be made in the familiar way, but can be applied as an index error to the measures of position on the plate. Suppose the meridian on the celestial sphere were a continuous bright line, and that the axis of the mirror were truly horizontal E. and W. (*i.e.*, no level and azimuth errors), but the mirror inclined to it at any angle. Then, whatever be the position of the mirror, the image of the meridian on the photographic plate would be the same curved line, part of a small circle parallel to the meridian and at an angular distance from it equal to twice the tilt of the mirror. A star would be on the meridian when its image fell on this fixed line, the position of which can be determined with reference to the seconds' marks on the plate.

15. *Level Error.*—A striding level may be applied to the pivots of the mirror in the usual way, or the method of reflection from mercury indicated in § 13 may be used. Or stars may be observed by reflection from mercury.

16. *Azimuth Error and Clock Error* are found from stars in the usual way.

A Photographic Zenith Tube.

17. The general principle of a moving photographic plate, which is rendered equivalent to a fixed plate by the marking of a fixed index, would appear to be advantageously applicable to the zenith tube, especially the floating zenith tube. The actual tube is not of much consequence, since we are not using it to bind object-glass and plate, and may be dispensed with altogether, or detached from the objective and used as a shield from stray-light merely. The important point is to have the index which marks the plate rigidly attached to the floating objective. For the present it is not necessary to specify the way in which the marking of the plate shall be accomplished; but let us suppose some lamp, or lamp and prism, or other source of light, firmly attached to the floating objective, and so arranged that it makes a spot of light on a plate placed in the focus of the objective, and first suppose this plate fixed. Further assume that there are suitable arrangements for rotating the objective and its index appliance in any azimuth.

18. Now suppose a star at rest in the zenith. On exposing the plate it will make a spot on the film; and a second spot will be made by the index—let us say at distance d and in azimuth ϕ. Rotate the objective through 180°. If the centre of the objective remains accurately in the same place the star will focus on exactly the same spot as before; and the index-mark will be at the same distance, d, from it in azimuth $\phi + 180°$. If, however, the objective is shifted laterally in the process of rotating it (which would, indeed, generally be the case in such an arrangement), the star image would no longer fall on the same spot as before, but would deviate from it by the amount of the lateral shift. But the index-spot would be displaced in exactly the same manner, and hence it would still be in the same position relatively to the star image—viz., at distance d and in azimuth $180° + \phi$. (In fact a lateral shift of the objective and index together is equivalent to a movement of the photographic plate, which we are going to admit freely.) Thus the mean positions of the index and the zenith coincide; and, similarly, if the star is not actually in the zenith, but at some distance from it, we obtain its zenith distance from two photographs in reversed positions.

19. In symbols let x and y be the rectangular coordinates of the star referred to the index dot, measured in any fixed directions; and let their values for the first exposure be x_1, y_1, and for the second x_2, y_2. Then

$$x_1 = +d \cos \phi \qquad y_1 = +d \sin \phi$$
$$x_2 = -d \cos \phi \qquad y_2 = -d \sin \phi$$

Here we assume that the plate is rotated through exactly

180°. There will probably be a slight error in doing this—say $\Delta\phi$. Then for the second pair of equations we must write

$$x_2 = -d\,(\cos\phi - \sin\phi\Delta\phi) \qquad y_2 = -d\,(\sin\phi + \cos\phi\,.\,\Delta\phi).$$

Thus

$$(x_1 + x_2) = d\sin\phi\,.\,\Delta\phi \qquad y_1 + y_2 = -d\cos\phi\,.\,\Delta\phi.$$

We can thus reduce the effect of error of orientation $\Delta\phi$ on the x coordinate to an insensible quantity by making $d\sin\phi$ small, and on the y coordinate by making $d\cos\phi$ small. But $d\cos\phi$ and $d\sin\phi$ are the coordinates of the index spot with respect to the zenith. Hence we must adjust the spot to be as nearly as possible at the zenith. Or two spots at equal zenith distances would do equally well, and would check the orientation of the plate.

20. Now, as in the case of the transit-circle, let the plate move so as to follow the image of the star, and get the benefit of a prolonged exposure, so that we may photograph faint stars in the zenith; and let the index-spot be recorded every second only. We can determine their R.A.'s and zenith distances by referring the stars to the index-spots. Whenever a sufficiently bright star is passing near the zenith, we may reverse the instrument during the transit, obtaining two images of the same star for determination of index error; or we may reverse between the transits of two stars whose relative places are known; or again, we may reverse in opposite senses on two different nights between the transits of any two stars known or unknown.

21. Almost the only adjustment required is the centring of the index-spot. The only constant required is the scale value in arc on the plate, which is shewn by the scale of seconds marks when the star does not trail. In addition the plate should be horizontal; the bed on which it moves can be probably levelled with sufficient accuracy by mechanical means, or the plate might be floated on mercury.

22. If a series of plates, or perhaps a long film, be arranged on a slide, or on a rotating horizontal tray, so that each in turn is presented for exposure, the whole zone of stars which passes the zenith might be photographed every clear night with comparatively little labour. An occasional reversal of the object-glass would give the constant of reduction.

23. *Other Applications.*—The principle of a moving plate, marked by a fixed index-spot, is applicable generally to the case of any instrument for determining positions. As another example we may take the fixed camera proposed by Capt. E. H. Hills, R.E. (*Monthly Notices*, vol. lv. p. 89), for determining longitudes by photography; an arrangement which may also be used for determining the place of the Moon. So long as we fix the plate to the camera, we are limited to bright stars; but we can extend the observations to faint stars by moving the plate as above.

University Observatory, Oxford:
1897 *March* 5.

The Sidereal System Revised in 1896. By Maxwell Hall.

The original article (*Memoirs R.A.S.* vol. xliii. p. 157) was revised in 1887 (*Monthly Notices*, vol. xlvii. p. 521); the present revision is undertaken to meet the determination by photography at the Potsdam Physical Observatory of the radial velocities of fifty-one stars, the determination by photography at the Oxford University Observatory of the annual parallaxes of about twenty-six stars of the second magnitude conveniently situated in that latitude, and to meet the recognition of the greater accuracy of the stellar proper motions as deduced by Dr. Auwers.

In the present revision the latter proper motions are always used when possible.

NOTE I. contains a list of those stars whose proper motions have been taken from other authorities.

NOTE II. contains a list of observed parallaxes; the means have been adopted.

NOTE III. contains the radial velocities observed by Dr. Huggins, at Greenwich, and at Potsdam. It is disappointing to find so many contradictory results; in the case of many stars the adopted means seem very uncertain.

It will be noticed that the general effect of the Potsdam observations is to greatly reduce all radial velocities; and it will be found that the Oxford parallaxes are much larger than the computed parallaxes; consequently it appears that there are large errors among the constants of the system hitherto adopted; and these large errors must first be ascertained before we can possibly proceed.

From the revision of 1887 the value of IIV was found to be 0″·10; and from the manner in which IIV and V enter the computations it will be seen that if IIV be still considered 0″·10, but that if V be reduced to 5 and II increased to 0″·02, then all the radial velocities will be diminished about one-half, and all the parallaxes will be nearly doubled.

Let us consider the effect of these changes on the very few stars whose parallaxes and radial velocities have both been ascertained with considerable accuracy:—

Star.	Observed. ϖ	Observed. $\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$
	"		"	
Sirius	0·27	0?	0·30	0
Arcturus	0·07	− 9	0·38	− 7
Capella	0·07	+ 7	0·06	+ 4
Rigel	0·03	+ 4	0·03	+ 9
Vega	0·12	− 9	0·16	−10
Procyon	0·23	+ 2	0·14	+ 4
α Orionis	0·02	+ 6	0·03	+ 7
Altair	0·20	− 8	0·32	− 7
Aldebaran	0·10	+11	0·04	+ 7
Polaris	0·05	− 6	0·02	− 6

Among these twenty results of computation the only serious difference between observation and computation occurs in the case of the parallax of *Arcturus*. Peters obtained 0″·127, Elkin 0″·016, so that the mean 0″·07 must yet be considered uncertain.

Omitting, then, the parallax of this star, the sums of the observed and computed parallaxes agree; and the sums of the observed and computed radial velocities, neglecting their signs, also agree.

In the following general computations there will be considerable saving of labour by employing only three decimal places for both natural numbers and logarithms instead of five, as before. In the case of any star the results depend upon its position and proper motion; and although the functions depending on position may be computed with accuracy, yet three places of decimals will clearly give as much numerical accuracy to the functions depending on proper motion as the uncertainty connected with proper motion will justify.

It was shown in the last revision that when failure occurred in computation such failure was generally due to the assumption of circularity of the star's orbit, and elliptic orbits were discussed.* We shall here give the cubic equation for u, so that in difficult cases it may be easily ascertained whether such failure exists or not—indeed, in cases where ρ_0 is not approximately known, much time may be saved by its use.

The cubic equation for u. $[v^2 = Fr_0^2.]$

$$\text{We have } u = \frac{K + a\Pi V}{H + \Pi\rho_0},$$

$$\text{and } \rho_0 = \frac{2V(au - b + H\Pi V)}{c^2 + u^2 - \Pi^2 V^2}.$$

* In the fig. *Monthly Notices*, vol. xlvii. p. 522, *dele* the letter ψ; and *dele* the words "the angle ACS," p. 523, line 8.

Multiply the last equation by Π, and add H to both sides, then

$$H + \Pi\rho_0 = \frac{2\Pi V(au - b + H\Pi V) + H(c^2 + u^2 - \Pi^2V^2)}{c^2 + u^2 - \Pi^2V^2}.$$

Invert, and multiply by $(K + a\Pi V)$; then

$$u = \frac{(K + a\Pi V)(c^2 + u^2 - \Pi^2V^2)}{2\Pi V(au - b + H\Pi V) + H(c^2 + u^2 - \Pi^2V^2)}.$$

Let

$$A = \frac{K - a\Pi V}{H};$$

$$B = c^2 + \Pi^2V^2 - \frac{2b\,\Pi V}{H};$$

$$C = \frac{K + a\Pi V}{H}(c^2 - \Pi^2V^2);$$

then

$$u^3 - Au^2 + Bu - C = 0.$$

This equation may easily be solved by approximation, and then

$$\rho_0 = \frac{K + a\Pi V - Hu}{\Pi u}.$$

Up to the present we have assumed that the stars are uniformly distributed, so that the force to the centre varies directly as r_0, and so that in circular orbits

$$v^2 = Fr_0^2.$$

But from considerations based upon the number and magnitude of the stars there is good reason to suppose that the number of the stars in an unit volume of space, or, in other words, that the star-density of space, varies inversely as the distance from the centre.

In this case the force to the centre is constant, and for circular orbits

$$v^2 = Fr_0.$$

Now this change in the law of force has little or no effect on the nearer stars; and in order to ascertain which law of force gives the better results we shall have to compute the parallaxes and radial velocities of the stars upon the two suppositions.

It will be convenient to collect all the formulæ for computation:

θ = North Polar Distance
ϕ = Right Ascension
} of a star, Jan. 1·0, 1850;

$\delta\theta$ = Annual proper motion in θ
$\delta\phi$ = Annual proper motion in ϕ
} in seconds of arc;

ϖ = Annual parallax, in seconds of arc;

$\rho_0 = \frac{1}{\varpi}$ = Distance in sidereal units;

$\frac{d\rho}{dt}$ = Annual change in distance, taking the radius of the Earth's orbit as the unit of space.

$$l = \sin\theta\cos\phi; \quad \delta l = n\delta\theta \,.\, \cos\phi - m\delta\phi;$$
$$m = \sin\theta\sin\phi; \quad \delta m = n\delta\theta \,.\, \sin\phi + l\delta\phi;$$
$$n = \cos\theta; \quad \delta n = -\sin\theta \,.\, \delta\theta.$$

$$a = l\lambda + m\mu + n\nu; \quad \log\lambda = -9{\cdot}166$$
$$b = \lambda\delta l + \mu\delta m + \nu\delta n; \quad \log\mu = -9{\cdot}914$$
$$c^2 = \delta l^2 + \delta m^2 + \delta n^2; \quad \log\nu = +9{\cdot}744.$$

$$H = lL + mM + nN; \quad \log L = -9{\cdot}936$$
$$K = L\delta l + M\delta m + N\delta n; \quad \log M = -9{\cdot}223$$
$$\log N = -9{\cdot}678.^*$$

$$V = 5; \quad \Pi V = 0{\cdot}100; \quad \Pi = 0{\cdot}020.$$

$$u = \frac{K + a\Pi V}{H + \Pi\rho_0}; \quad \frac{d\rho}{dt} = -u\rho_0.$$

Then for $v^2 = Fr_0^{-2}$ we have

$$\rho_0 = \frac{2V(au - b + H\Pi V}{c^2 + u^2 - \Pi^2V^2}.$$

And for $v^2 = Fr_0$ we have

$$\rho_0 = \frac{2V\left(au - b + \frac{H\Pi V}{1 + \Pi r_0}\right)}{c^2 + u^2 - \frac{\Pi^2V^2}{1 + \Pi r_0}}$$

where $r_0^2 = R_0^2 + \rho_0^2 + 2HR_0\rho_0$.

or $\Pi r_0 = \sqrt{1 + \Pi^2\rho_0^2 + 2H\Pi\rho_0}$.

The following example for $v^2 = Fr_0^2$ is given. Much labour may be saved by using printed forms.

* Instead of $-9{\cdot}677$, so that $L^2 + M^2 + N^2$, to three decimal places, may equal 1·000.

[Example.]

α Lyræ. M = 0·2

R.A. = 18ʰ 31ᵐ 51ˢ; P.M. in R.A. = +0ˢ·0173
N.P.D. = 51° 21′; P.M. in N.P.D. = −0″·295 } Auwers

$\theta = 51° 21'$; $\delta\theta = -0{\cdot}295$
$\phi = 277\ 58$; $\delta\phi = +0{\cdot}260$

$\log \sin \theta = +9{\cdot}893$ $\quad +9{\cdot}893$
$\log \cos \phi = +9{\cdot}142$; $\log \sin \phi = -9{\cdot}996$
$\log l = +9{\cdot}035$; $\quad \log m = -9{\cdot}889$; $\log n = +9\ 796$

$\log n = +9{\cdot}796$
$\log \delta\theta = -9{\cdot}470$
$-9{\cdot}266$

$\log \cos \phi = +9{\cdot}142$
$-8\overline{1}408 = -{\cdot}026$

$-9{\cdot}266$
$\log \sin \phi = -9{\cdot}996$
$+9{\cdot}262 = +{\cdot}183$

$\log m = -9{\cdot}889$
$\log \delta\phi = +9{\cdot}415$
$-9{\cdot}304^{*} = +{\cdot}201$
$\delta l = +{\cdot}175$

$\log l = +9{\cdot}035$
$+9{\cdot}415$
$+8{\cdot}450 = +{\cdot}028$
$\delta m = +{\cdot}211$

$\log \delta l = +9{\cdot}243$; $\delta l^2 = {\cdot}030\ 6$
$\log \delta m = +9{\cdot}324$; $\delta m^2 = {\cdot}044\ 5$
$\log \delta n = +9{\cdot}363$; $\delta n^2 = {\cdot}053\ 2$
$c^2 = {\cdot}128$

$\log \lambda = -9{\cdot}166$
$\log l = +9{\cdot}035$
$-8{\cdot}201 = -{\cdot}016$

$\log \lambda = -9{\cdot}166$
$\log \delta l = +9{\cdot}243$
$-8{\cdot}409 = -{\cdot}026$

$\log \mu = -9{\cdot}914$
$\log m = -9{\cdot}889$
$+9{\cdot}803 = +{\cdot}635$

$\log \mu = -9{\cdot}914$
$\log \delta m = +9{\cdot}324$
$-9{\cdot}238 = -{\cdot}173$

$\log \nu = +9{\cdot}744$
$\log n = +9{\cdot}796$
$+9{\cdot}540 = +{\cdot}347$
$a = +{\cdot}966$

$\log \nu = +9{\cdot}744$
$\log \delta n = +9{\cdot}363$
$+9{\cdot}107 = +{\cdot}128$
$b = -{\cdot}071$

* Change the sign.

$\log L = -9{\cdot}936$
$\log l = +9{\cdot}035$
$-8{\cdot}971 = -{\cdot}094$

$\log M = -9{\cdot}223$
$\log m = -9{\cdot}889$
$+9{\cdot}112 = +{\cdot}130$

$\log N = -9{\cdot}678$
$\log n = +9{\cdot}796$
$-9{\cdot}474 = -{\cdot}298$
$H = -{\cdot}262$

$\log L = -9{\cdot}936$
$\log \delta l = +9{\cdot}243$
$-9{\cdot}179 = -{\cdot}151$

$\log M = -9{\cdot}223$
$\log \delta m = +9{\cdot}324$
$-8\,547 = -{\cdot}035$

$\log N = -9\,678$
$\log \delta n = +9{\cdot}363$
$-9{\cdot}041 = -{\cdot}110$
$K = -{\cdot}296$
$a\Pi V = +{\cdot}097$
$K + a\Pi V = -{\cdot}199$
$\log. = -9{\cdot}299$

Assume $\rho_0 = 6{\cdot}4$
$\Pi\rho_0 = {\cdot}128$
$H + \Pi\rho_0 = -{\cdot}134$;

$\log = -9{\cdot}127$
$\log u = +10{\cdot}172$
$\log a = +9{\cdot}985$
$\log au = +10{\cdot}157$

$c^2 = 0{\cdot}128$
$u^2 = 2{\cdot}208$
$-\Pi^2V^2 = -{\cdot}010$
$2{\cdot}326$

$au = +1{\cdot}436$
$-b = +{\cdot}071$
$H\Pi V = -{\cdot}026$
$1{\cdot}481$

And $\dfrac{1{\cdot}481 \times 10}{2{\cdot}326} = 6{\cdot}4 = \rho_0$

Therefore $\varpi = 0''{\cdot}16$
and $\dfrac{d\rho}{dt} = -10$

No.	Star.	M.	R.A. 1850.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $v'=Fr_0^2$		$v'=Fr_0$		Notes.
							ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
1	α Canis Maj. (*Sirius*)	−1·2	6 38 32	−0·0372	106 31	+1·199	0·27	0?	0·30	0	0·30	0	$\frac{d\rho}{dt}$ var.
2	α Argûs (*Canopus*)	−0·4	6 20 37	·0000	142 37	0·000	0·03	...	...	...	...	...	The P.M.'s are zero.
3	α Boötis (*Arcturus*)	0·0	14 8 49	−·0799	70 2	+1·977	0·07	−9	0·38	−7	0·38	−7	
4	α Centauri	0·0	14 29 27	−·4842	150 13	−0·747	0·72	...	large	−1	large	−1	$\rho_0=0·6$, $\varpi=1''·67$, in both cases.
5	Aurigæ (*Capella*)	0·1	5 5 37	+·0079	44 10	+0·424	0·07	+7	0·06	+4	0·06	+5	
6	β Orionis (*Rigel*)	0·2	5 7 20	−·0012	98 23	−0·005	0·03	+4	0·03	+9	0·03	+9	
7	α Lyræ (*Vega*)	0·2	18 31 51	+·0173	51 21	−0·295	0·12	−9	0·16	−10	0·16	−10	
8	α Canis Min. (*Procyon*)	0·5	7 31 27	−·0474	84 24	+1·027	0·23	+2	0·14	+4	0·14	+4	
9	α Orionis	0·9	5 47 3	+·0008	82 38	−0·024	0·02	+6	0·03	+7	0·03	+7	
10	α Aquilæ (*Altair*)	1·0	19 43 28	+·0351	81 32	−0·384	0·20	−8	0·32	−7	0·32	−7	$\frac{d\rho}{dt}$ var.
11	α Tauri (*Aldebaran*)	1·1	4 27 19	+·0035	73 48	+0·184	0·10	+11	0·04	+7	0·04	+7	
12	α Virginis (*Spica*)	1·1	13 17 18	−·0044	100 23	+0·018	...	−4	...	...	0·00	−2	$\rho_0=265$; $r_0=298$.
13	β Gemin. (*Pollux*)	1·2	7 36 8	−·0481	61 37	+0·051	0·06	−7?	...	...	...	...	
14	α Leonis (*Regulus*)	1·3	10 0 23	−·0182	77 18	−0·018	0·09	+1	0·03	+5	0·04	+4	
15	α Cygni	1·4	20 36 19	−·0003	45 15	−0·003	0·01	−7	0·01	−8	0·01	−8	
16	α Gemin. (*Castor*)	1·5	7 25 1	−·0151	57 47	+0·079	...	+1?	...	...	...	...	

No.	Star.	M.	R.A. 1830.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $v^2=Fr_0^3$		$v^2=Fr_0$		Notes.
							v	$\frac{d\rho}{dt}$	v	$\frac{d\rho}{dt}$	v	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
17	γ Orionis	1·8	5 17 5	+ ·002	83 47	+0·04	...	+ 2	0·04	+ 8	0·04	+ 8	
18	ε Orionis	1·8	5 28 36	− ·0018	91 18	−0·006	...	+ 6	0·03	+ 9	0·03	+ 9	
19	ζ Orionis	1 8	5 33 12	− ·0008	92 2	−0·010	...	+ 3	0·03	+ 9	0·03	+ 9	
20	ε Ursæ Maj.	1·8	12 47 25	+ ·0115	33 14	+0·021	0·08	− 1?	0·06	− 3	0·07	− 3	
21	α Persei	1·9	3 13 38	+ ·0015	40 41	+0·033	0·09	− 6	0·02	+ 1	0·02	+ 2	K zero; computed $\frac{d\rho}{dt}$ doubtful.
22	β Tauri	1·9	5 16 49	+ ·0013	61 31	+0·180	0·06	− 2?	0·04	+ 7	0·04	+ 7	
23	α Ursæ Maj.	1·9	10 54 26	− ·0180	27 26	+0·071	0·05	− 9	0·16	− 6	0·15	− 6	
24	η Ursæ Maj.	1·9	13 41 37	− ·0115	39 56	+0·014	...	− 6	0·01	− 5	0·01	− 5	
25	β Aurigæ	2·0	5 48 32	− ·0065	45 4	+0·011	0·06	− 6	0·01	+ 5	...	...	
26	α Androm.	2·1	0 0 39	+ ·0095	61 44	+0·156	0·06	− 4?	0·03	− 1	0·03	− 1	
27	α Ursæ Min. (*Polaris*)	2·1	1 5 1	+ ·1109	1 29	+0·002	0·05	− 6	0·02	− 6	0·02	− 6	
28	γ Androm.	2·1	1 54 43	+ ·0021	48 24	+0·051	...	− 3	0·02	+ 1	0·00	0	For Fr_0, $\rho_0=300$.
29	α Arietis	2·1	1 58 44	+ ·0127	67 15	+0·134	0·08	− 4	0·03	+ 3	0·03	+ 4	
30	γ Gemin.	2 1	6 29 3	+ ·0023	73 29	+0·035	...	− 4	0·10	+ 6	0·10	+ 6	
31	γ Cassiopeæ	2·2	0 47 42	+ ·0013	30 6	+0·015	0·01	− 4	0·02	− 3	0·01	− 5	

No.	Star.	M.	R.A. 1850.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $v^2=Fr_0^2$		Computed. $v^2=Fr_0$		Notes.
							$\overline{w}$	$\frac{d\rho}{dt}$	$\overline{w}$	$\frac{d\rho}{dt}$	$\overline{w}$	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
32	β Androm.	2·2	1 1 21	+ ·0144	55 11	+0·084	0·07	+ 2	0·03	+ 1	0·03	+ 1	
33	δ Orionis	2·2	5 24 21	− ·0014	90 25	+0·005	...	0	0·03	+ 9	0·03	+ 9	
34	γ Leonis	2·2	10 11 42	+ ·0208	69 24	+0 136	...	− 9	...	...	...	...	
35	β Leonis	2·2	11 41 24	− ·0356	74 35	+0 098	0 03	− 3	0·05	+ 1	0·05	+ 1	
36	ζ Ursæ Maj.	2·2	13 17 53	+ ·0134	34 17	+0·022	...	0?	0·07	− 3	0·08	− 3	
37	β Ursæ Min.	2·2	14 51 12	− ·0077	15 14	+0·005	0·02	+ 3	0·03	− 8	0·03	− 8	$\frac{d\rho}{dt}$ var.
38	α Ophiuchi	2·2	17 27 58	+ ·0066	77 20	+0·217	...	0?	0 03	− 5	0·03	− 5	
39	α Coronæ	2·3	15 28 20	+ ·0085	62 47	+0·094	...	+ 7	0·02	− 3	0·04	− 3	
40	γ Cygni	2·3	20 16 51	− ·0001	50 13	−0·020	0·10	− 3	0·02	− 8	0·02	− 8	
41	β Cassiopeæ	2·4	0 1 12	+ ·0658	31 41	+0·190	0·16	0	c 06	− 4	0 06	− 4	
42	α Cassiopeæ	2·4	0 32 2	+ ·0035	34 17	+0 038	0·04	− 3	0·02	− 3	0·02	− 4	
43	β Persei (*Algol*)	2·4	2 58 26	− ·0017	49 38	−0·010	0·05	0	0·01	+ 2	0·01	+ 2	
44	β Ursæ Maj.	2·4	10 52 45	+ ·0085	32 49	−0 047	0·08	+ 1?	0·21	− 1	0 23	− 1	
45	γ Ursæ Maj.	2·4	11 45 55	+ ·0098	35 28	−0·008	0·10	0?	0·09	− 2	0·11	− 2	
46	γ Draconis	2 4	17 53 8	− ·0018	38 29	+0·028	0·07	− 2	0·03	− 9	0·02	− 9	
47	ε Pegasi	2·4	21 36 49	+ ·0008	80 49	−0 011	0 08	− 2?	0 02	− 4	...	...	
48	α Pegasi	2 4	22 57 18	+ ·0028	75 36	+0 030	0·08	− 4?	0·02	− 3	...	...	

No.	Star.	M.	R.A. 1850.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $v^2=Fr_0^3$		Computed. $v^2=Fr_0$		Notes.
							ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
49	ϵ Boötis	2·6	14 38 26	− ·0043	62 17	−0·001	...	− 4	...	...	...	...	
50	α Cephei	2 6	21 15 0	+ ·0211	28 3	−0·025	0·06	−14	0·04	− 8	0·03	− 8	
51	β Pegasi	2·6	22 56 30	+ ·0130	62 44	−0·133	...	+ 1	0·45	0	0·08	− 1	
52	β Libræ	2 7	15 8 56	− ·0079	98 50	+0·017	...	− 2	0·00	− 6	0·01	− 4	For Fr_0^3, $\rho_0=375$.
53	α Serpentis	2·7	15 36 53	+ ·0079	83 6	−0·056	...	+ 5	...	...	...	...	
54	ϵ Cygni	2·7	20 40 9	+ ·0280	56 35	−0·335	0·13	...	0·10	− 6	0·10	− 6	
55	δ Leonis	2·8	11 6 7	+ ·0102	68 39	+0·115	...	− 3	0·21	− 1	0·80	0	
56	β Herculis	2 8	16 23 46	− ·0090	68 11	+0·015	...	− 8	0·01	− 9	0·02	− 8	
57	ι Ursæ Maj.	3·2	8 48 55	− ·0441	41 22	+0·247	0·13	...	large	− 2	large	− 2	$\rho_0=0·6$, $\varpi=1''·67$, in both cases.
58	θ Ursæ Maj.	3·2	9 22 48	− ·1041	37 39	+0·564	0·05	...	large	− 3	large	− 3	$\rho_0=0·4$, $\varpi=2''·63$, in both cases.
59	α Herculis	3 2	17 7 49	− ·0019	75 26	−0·030	0·05	...	...	...	...	...	
60	δ Herculis	3·3	17 8 52	− ·005	64 59	+0·15	0·08	...	0·04	−10	0·04	−10	
61	π Herculis	3·4	17 9 50	− ·0035	53 1	−0·005	0·11	...	large	−10	large	−10	$\rho_0=1·0$, $\varpi=1''·00$, in both cases.
62	η Cassiopeæ	3·5	0 40 3	+ ·1346	32 59	+0·481	0·31	...	0·14	− 2	0·13	− 2	
6	η Herculis	3·7	16 37 45	+ ·0028	50 47	+0·077	0·40	...	...	...	...	...	

No.	Star.	M.	R.A. 1850.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $v^0 = Fr_0^3$		Computed. $v^2 = Fr_0$		Notes.
							ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
64	10 Ursæ Maj.	4·2	8 50 53	− ·036	47 38	+0·28	0·20	...	large	+ 1	large	+ 1	$\rho_0 = 0·21$, $\varpi = 4''·76$, in both cases. This star is B A C 3059.
65	70 (p) Ophiuchi	4·3	17 57 53	+ ·0131	87 28	+1·109	0·22	...	0·22	− 9	0·22	− 9	
66	θ Cassiopeæ	4·4	1 2 0	+ ·0233	35 39	+0·024	0·23	...	0·05	+ 1	0·04	+ 2	
67	e Eridani	4·4	3 13 55	+ ·270	133 39	−0·75	0·14	...	0·67	+ 9	0·67	+ 9	
68	o^2 Eridani	4·4	4 8 22	− ·1442	97 53	+3·442	0·19	...	large	+ 1	large	+ 1	$\rho_0 = 0·90$, $\varpi = 1''·10$, and $\rho_0 = 0·93$, $\varpi = 1''·08$, respectively
69	8 Ursæ Min.	4·4	18 20 44	+ ·0256	3 24	−0·040	0·03	...	0·03	− 6	0·03	− 6	
70	8 Equulei	4·6	21 7 11	+ ·012	80 36	+0·30	0·04	...	0·09	+ 1	0·08	+ 1	
71	σ Draconis	4·7	19 32 38	+ ·0973	20 36	+1·766	0·25	...	large	0	large	0	$\rho_0 = 0·23$, $\varpi = 4''·35$, and $\rho_0 = 0·28$, $\varpi = 3''·57$, respectively
72	ν^2 Draconis	4·8	17 29 19	+ ·0179	34 43	−0·044	0·28	...	0·11	−10	0·11	−10	
73	ν^1 Draconis	4·9	17 29 14	+ ·0183	34 43	−0·048	0·32	...	0·12	− 9	0·12	− 9	
74	ζ Toucani	5·0	0 12 12	+ ·273	155 45	−1·16	0·06	...	large	+ 7	large	+ 7	$\rho_0 = 0·39$, $\varpi = 2''·54$, in both cases.
75	61 Cygni	5·0	21 0 11	+ ·3444	51 59	−3·230	0·43	...	0·88	− 5	0·87	− 5	
76	μ Cassiopeæ	5·2	0 58 19	+ ·3860	35 49	+1·580	0·18	...	0·40	− 1	0·40	− 1	

No.	Star.	M.	R.A. 1850.	P.M. in R.A.	N.P.D. 1850.	P.M. in N.P.D.	Observed.		Computed. $\epsilon^2=Fr_0^2$		$\epsilon^2=Fr_0$		Notes.
							ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	ϖ	$\frac{d\rho}{dt}$	
			h m s	s	° ′	″	″		″		″		
77	ε Indi	5·2	21 51 51	+ ·480	147 24	+ 2·60	0·22	...	0·58	+ 5	0·58	+ 5	
78	Cephei 51 (Her.)	5·3	6 28 33	− ·0400	2 45	+ 0·051	0·03	...	0·03	− 6	0·03	− 6	
79	3077 Bradley	5·5	23 6 4	+ ·249	33 40	− 0·287	0·18	...	0·25	− 3	0·25	− 3	
80	85 Pegasi	5·8	23 54 21	+ ·0622	63 43	+ 0·980	0·06	...	0·14	− 1	0·14	− 1	
81	20 Leonis Min.	6·0	9 52 21	− ·0431	57 20	+ 0·427	0·06	...	0·12	− 8	0·12	− 8	
82	1830 Groombridge	6·4	11 44 19	+ ·3461	51 12	+ 5·776	0·13	...	large	− 3	large	− 3	$\rho_0=0''·18$, $\varpi=5''·56$, in both cases.
83	1618 Groombridge	6·5	10 2 6	− ·1390	39 48	+ 0·501	0·25	...	large	0	large	0	$\rho_0=0''·006$ and $0''·005$.
84	Σ 1516	7·0	11 5 16	− ·1029	15 43	− 0·117	0·15	...	0·21	− 7	0·21	− 7	
85	21185 Lalande	7·5	10 55 8	− ·0453	53 2	+ 4·716	0·46	...	large	− 4	large	− 4	$\rho_0=0''·4$, $\varpi=2''·50$, in both cases.
86	9352 Lacaille	7·5	22 56 0	+ ·5672	126 43	− 1·306	0·28	...	large	− 1	large	− 1	$\rho_0=0''·115$ in both cases
87	Σ 2398	7·7	18 41 0	− ·1726	30 35	− 1·896	0·35	...	...	...	...	...	
88	34 Groombridge	8·1	0 9 52	+ ·2551	46 50	− 0·366	0·31	...	0·39	− 1	0·38	− 1	
89	21 258 Lalande	8·5	10 58 0	− ·4004	45 42	− 0·943	0·23	...	...	...	...	...	
90	17 415 Oelt. Argel.	9·0	17 37 17	− ·0679	21 33	+ 1·213	0·20	...	...	...	...	...	
91	11 677 Oelt. Argel.	9·5	11 12 0	− 0·507	23 20	− 0·21	0·18	...	large	− 7	large	− 7	$\rho_0=0''·6$, $\varpi=1''·67$, in both cases.

It thus appears that the results from $v^2=Fr_0^2$ are identical with those from $v^2=Fr_0$ in 50 cases; that the results from the former equation are better than those from the latter in 10 cases; but that the differences are important in only 4 cases;* that the results from the latter equation are better than those from the former in 11 cases, but that the difference is important in only 1 case;† and that in the remaining 20 cases the results are either unknown or doubtful.

The present researches therefore show that the results from the two equations are nearly the same, but that those from

$$v^2=Fr_0^2$$

are slightly preferable to those from the other; and in consequence $v^2=Fr_0^2$ should certainly be adopted, although no doubt in any special case, as in No. 12, a solution may be obtained from $v^2=Fr_0$, the circumstance being duly noted.

The results of the above computations may be thus roughly analysed:—

Of the 72 stars observed for parallax, in 49 cases the computations are more or less correct, in 15 cases doubtful, in 1 case wrong, and in 7 cases impossible.

Of the 53 stars observed for radial velocity, in 28 cases the computations are more or less correct, in 13 cases doubtful, in 5 cases wrong, and in 7 cases impossible.

This is a very great improvement upon the revision of 1887, and we are therefore encouraged to look for still closer agreement between observation and theory; at present 3 stars out of every 5 revolve in orbits more or less circular round the common centre, and 2 stars out of every five revolve in orbits more or less elliptic; and it is of course impossible to say at present what degree of circularity will be ultimately obtained.

In our search for further improvement the first matter for consideration is the position of the solar apex, or the point towards which the Sun moves; from the earlier investigations we found

$$\left.\begin{aligned}\alpha &= 259^\circ 8\\ \beta &= 56\cdot4\end{aligned}\right\}\ 1850;$$

but recent investigations show that while β is tolerably correct, α should be considerably increased:—

	α	β		α	β
Dunkin	263°·7	65°·0	L. Struve	273°·3	62°·7
L. de Ball	269·0	66·8	Plummer	273·1	66·6
Rancken	284·6	58·1	Boss	283·3	45·9
Bischof	285·2	41·5	Stumpe	285·0	53·8
Ubaghs	262·4	63·4	Porter	281·2	49·3

* Nos. 25, 47, 48, and 55. † No. 12.

But if we still assume that the solar orbit is circular, a considerable increase in a will require a considerable increase in the R.A. of the centre; and this is out of the question in the present state of the theory.

It will therefore be advisable to find corrections to the adopted positions of the Centre and Apex, removing the restriction that they must be 90° apart; but as this will involve 5 corrections, it will be further advisable to attempt the complete solution and find the 7 corrections, $\Delta\lambda$, $\Delta\mu$, ΔL, ΔM, ΔV, $\Delta\Pi$, and $\Delta\Lambda$, the necessity of which was foreseen in the Revision of 1887, page 539.

We now have

$$F = \Pi^2V^2(1-\Lambda);$$

$$v^2 = Fr_0^2;$$

$$r_0^2 = R_0^2 + 2HR_0\rho_0 + \rho_0^2;$$

$$u = \frac{K + a\Pi V + \varpi\Gamma V}{H + \Pi\rho_0};$$

$$\Gamma = L\lambda + M\mu + N\nu;$$

$$\rho_0 = \frac{2V(au - b + H\Pi V)}{c^2 + u^2 - \Pi^2V^2 + \Lambda\varpi^2V^2 \cdot \Pi^2r_0^2};$$

$$\frac{d\rho_0}{dt} + u\rho_0 = 0;$$

$$\varpi = \frac{1}{\rho_0}.$$

With regard to the factor $\Pi^2r_0^2$ in the term whose coefficient is Λ, whenever ϖ is equal to or greater than $0''.1$, $\Pi^2r_0^2$ may be taken equal to 1.

Let

$$\epsilon = 2\varpi V(au - b + H\Pi V) - (c^2 + u^2 - \Pi^2V^2) - \Lambda \cdot \varpi^2V^2 \cdot \Pi^2r_0^2,$$

so that if all the quantities have been rightly taken

$$\epsilon = 0.$$

Again let

$$S = \frac{\varpi\left(aV + \frac{d\rho}{dt}\right)}{H + \Pi\rho_0}$$

$$P = \frac{L}{N};\quad Q = \frac{M}{N};$$

$$p = \frac{\lambda}{\nu};\quad q = \frac{\mu}{\nu};$$

$$U = \delta l - P\delta n - u(l - nP) + \varpi V(\lambda - \nu P);$$

$$W = \delta m - Q\delta n - u(m - nQ) + \varpi V(\mu - \nu Q);$$

then

$$\frac{d\epsilon}{d\varpi} = 2V(au - b + H\Pi V) - 2S\left(\frac{d\rho}{dt} \cdot \Pi\rho_0 - \Gamma V\right) - 2\Lambda V^2(\varpi + H\Pi)\,;$$

$$\frac{d\epsilon}{d\lambda} = 2\varpi V\{u(l - np) - (\delta l - p\delta n)\} + 2SV\{\Pi(l - np) + \varpi(L - Np)\}\,;$$

$$\frac{d\epsilon}{d\mu} = 2\varpi V\{u(m - nq) - (\delta m - q\delta n)\} + 2SV\{\Pi(m - nq) + \varpi(M - Nq)\}\,;$$

$$\frac{d\epsilon}{dL} = 2SU + 2\varpi V \cdot \Pi V(l - nP)(1 - \Lambda)\,;$$

$$\frac{d\epsilon}{dM} = 2SW + 2\varpi V \cdot \Pi V(m - nQ)(1 - \Lambda)\,;$$

$$\frac{d\epsilon}{dV} = 2\varpi(au - b + H\Pi V) + 2S(\Pi a + \varpi\Gamma) + 2\Pi V(\Pi + H\varpi) - 2\Lambda\varpi^2 V \cdot \Pi^2\rho_0^2\,;$$

$$\frac{d\epsilon}{d\Lambda} = -\varpi^2 V^2 \cdot \Pi^2\rho_0^2\,;$$

$$\frac{d\epsilon}{d\Pi} = 2S\left(aV + \frac{d\rho}{dt}\right) + 2\varpi V^2(H + \Pi\rho_0)(1 - \Lambda)\,;$$

where both Γ and Λ are zero at present.

Again let

$$\frac{d\epsilon}{d\lambda} = \mathfrak{A}\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{d\mu} = \mathfrak{B}\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{dL} = A\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{dM} = B\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{dV} = C\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{d\Lambda} = D\frac{d\epsilon}{d\varpi},$$

$$\frac{d\epsilon}{d\Pi} = E\frac{d\epsilon}{d\varpi};$$

then

$$\mathfrak{A} \cdot \Delta\lambda + \mathfrak{B} \cdot \Delta\mu + A \cdot \Delta L + B \cdot \Delta M + C \cdot \Delta V + D \cdot \Delta\Lambda + E \cdot \Delta\Pi + \Delta\varpi = 0$$

where $\Delta\lambda$, $\Delta\mu$, ΔL, &c., are the corrections to be applied to the assumed values of λ, μ, L, &c, and where $\Delta\varpi$ is the observed minus the computed parallax.

Similarly if

$$G = \frac{\varpi^2(H + \Pi\rho_0)}{u\,H},$$

then

$$\mathfrak{A} \cdot \Delta\lambda + \mathfrak{B} \cdot \Delta\mu + A \cdot \Delta L + B \cdot \Delta M + C \cdot \Delta V + D \cdot \Delta\Lambda + E \cdot \Delta\Pi + G \cdot \Delta\frac{d\rho}{dt} = 0$$

where $\Delta\dfrac{d\rho}{dt}$ is the observed minus the computed radial velocity.

Note I.

The proper motions employed in this article were those found by Dr. Auwers, and were taken from the Greenwich Ten-Year Catalogue of Stars for 1880, excepting:—

No.	Star.	Authority.
2	α Argûs	*Nautical Alm.*, 1896.
4	α Centauri	Elkin, *Mem.*, vol. xlviii. p. 14.
17	γ Orionis	Main, „ „ xix. p. 142.
60	δ Herculis	„ „ „ xxviii. p. 134.
64	10 Ursæ Maj.	B. A. C., 3059.
67	e Eridani	Elkin, *Mem.*, vol. xlviii. p. 175.
70	δ Equulei	Stone, „ „ xxxiii. p. 73.
74	ζ Toucani	Elkin, „ „ xlviii. p. 168.
77	ε Indi	„ „ „ xlviii. p. 119.
82	1830 Groomb.	Argelander, Gr. Ten-Year Cat., 1880.
83	1618 Groomb.	„ „ „
84	Σ. 1516	„ „ „
85	21, 185 Lalande	„ „ „
86	9352 Lacaille	Gould, *Mem.*, vol. xlviii. p. 140.
87	Σ. 2398	Lamp., *Astr. Nach.*, 2676 and 2807.
88	34 Groomb.	Argelander, Gr. Ten-Year Cat., 1880.
89	21,258 Lalande	„ „ „
90	17,415 Oeltz. Arg.	„ „ „
91	11,677 Oeltz. Arg.	Geelmuyden, *Astr. Nach.*, 2287.

Note II.

The following parallaxes are employed in the above article, the means of different results being taken when possible. For many of them I am indebted to a Catalogue of Stellar Parallax, by the late Dr. Pritchard (*Ast. Obs. made at the Univ. Obs. Oxford*, No. IV.):—

No.	Star.	Parallax.	Authority.
1	Sirius	0″·23	Henderson, *Mem.* vol. xi. p. 239.
		0·27	Abbe, *M.N.* vol. xxviii. p. 6.
		0·193	Gyldén.
		0·381	Gill and Elkin, *Mem.* vol. xlviii. p. 187.
		0·268	Mean.
2	Canopus	0·028	Elkin, *Mem.* vol. xlviii. p. 183.
3	Arcturus	0·127	Peters.
		0·016	Elkin, *Report Yale Coll. Obs.*
		0·072	Mean.
4	α Centauri	0·913	Henderson and Maclear, *Mem.* vol. xii. p. 370.

No.	Star.	Parallax.	Authority.
		0″·919	Maclear, *Mem.* vol. xx. p. 98.
		0·916	Mean from zenith distances.
		0·880	Moesta at Santiago,
		0·521	„ *Observatory*, vol. iii. p. 662.
		0·512	Elkin, *M.N.* vol. xli. p. 223.
		0·752	Gill and Elkin, *Mem.* vol. xlviii. p. 186.
		0·716	Mean.
5	Capella	0·046	Peters.
		0·095	Elkin, *Yale Coll. Obs.*
		0·070	Mean.
6	Rigel	−0·004	Gill } *Cat. Stellar Par.*
		0·055	Schur }
		0·026	Mean.
7	Vega	0·06 ?	Airy, *Mem.* vol. x. p. 265.
		0·155	W. Struve, Peters, and O. Struve, *M. N.* vol. xiii. p. 74.
		0·103	Peters, *Cosmos*, vol. iii. p. 261.
		0·188	Brünnow, *Dunsink Obs.* vol. ii.
		0·134	A. Hall, *Nature*, vol. xxxv. p. 258.
		0·092	Elkin, *Yale Coll. Obs.*
		0·122	Mean.
8	Procyon	0·123	Auwers.
		0·341	Elkin, *Yale Coll. Obs.*
		0·232	Mean.
9	α Orionis	0·022	Elkin, *Yale Coll. Obs.*
10	Altair	0·181	Struve, *Mem.* vol. xii. p. 29.
		0·214	Elkin, *Yale Coll. Obs.*
		0·198	Mean.
11	Aldebaran	0·102	A. Hall, *Nature*, vol. xxxvi. p. 138.
		0·101	Elkin, *Yale Coll. Obs.*
		0·102	Mean.
13	Pollux	0·057	Elkin, *Yale Coll. Obs.*
14	Regulus	0·089	„ „ „
15	α Cygni	0·012	„ „ „
20	ε Ursæ Maj.	0·081	Pritchard.
21	α Persei	0·087	„
22	β Tauri	0·063	„
23	α Ursæ Maj.	0·046	„

No.	Star.	Parallax.	Authority.
25	β Aurigæ	0″062	Pritchard.
26	α Androm.	0·058	,,
27	Polaris	0·067	Peters.
		0·025	Schweizer.
		0·015	L. de Ball, *Observatory*, vol. viii. p. 314.
		0·079	Pritchard.
		0·046	Mean.
29	α Arietis	0·080	Pritchard.
31	γ Cassiop.	0·012	,,
32	β Androm.	0·074	,,
35	β Leonis	0·029	,,
37	β Ursæ Min.	0·022	,,
40	γ Cygni	0·102	,,
41	β Cassiop.	0·164	,,
42	α Cassiop.	0·036	,,
43	β Persei	0·058	,,
		0·036	Chase, *Observatory*, vol. xvii. p. 253.
		0·047	Mean.
44	δ Ursæ Maj.	0·080	Pritchard.
45	γ Ursæ Maj.	0·099	,,
46	γ Draconis	0·092	Molyneux, *Nature*, vol. xviii. p. 669.
		0·050	Pritchard.
		0·071	Mean.
47	ε Pegasi	0·080	Pritchard.
48	α Pegasi	0·082	,,
50	α Cephei	0·062	,,
54	ε Cygni	0·128	,,
57	ι Ursæ Maj.	0·133	Peters.
58	θ Ursæ Maj.	0·052	Kapteyn, *Cat. Stellar Par.*
59	α Herculis	0·050	Jacob, *Mem.* vol. xxviii. p. 45.
60	δ Herculis	0·084	Leavenworth, *Cat. Stellar Par.*
61	π Herculis	0·11	Belopolsky, ,, ,, ,,
62	η Cassiop.	0·234	Struve, ,, ,, ,,
		0·257	Schweizer, *M.N.* vol. lv. p. 341.
		0·443	Davis, ,, ,, ,,
		0·311	Mean.
63	η Herculis	0·40	Belopolsky, *Cat. Stellar Par.*
64	10 Ursæ Maj.	0·20	,, ,, ,, ,,

No.	Star.	Parallax.	Authority.
65	70 (p) Ophi.	0″·150	Krüger.
		0·286	Schur, *Observatory*, vol. xvii. p. 252.
		0·218	Mean.
66	θ Cassiop.	0·232	Jacoby, *Annals New York Academy of Sciences*, vol. viii.
67	e Eridani	0·136	Elkin, *Mem.* vol. xlviii. p. 178.
68	o^2 Eridani	0·166	Gill, „ „ „ p. 160.
		0·223	A. Hall, *Observatory*, vol. viii. p. 345.
		0·194	Mean.
69	δ Ursæ Min.	0·034	L. de Ball, *Observatory*, vol. viii. p. 314.
70	δ Equulei	0·035	Leavenworth, *Cat. Stellar Par.*
71	σ Draconis	0·246	Brünnow, *Dunsink Obs.* vol. i.
72	ν^2 Draconis	0·28	Belopolsky, *Cat. Stellar Par.*
73	ν^1 Draconis	0·32	„ „ „ „
74	ζ Toucani	0·057	Elkin, *Mem.* vol. xlviii. p. 171.
75	61 Cygni	0·374	Bessel corrected by Peters.
		0·349	Peters, *Cosmos*, vol. iii. p. 260.
		0·505	O. Struve, *Cat. Stellar Par.*
		0·553	Auwers, *M.N.* vol. xxiii. p. 74.
		0·414	Schweizer, *Cat. Stellar Par.*
		0·416	Socoloff, „ „ „
		0·466	Ball, *M.N.* vol. xl. p. 250 and vol. xli. p. 164.
		0·525	Belopolsky, *Cat. Stellar Par.*
		0·270	A. Hall, *Nature*, vol. xxxv. p. 258.
		0·434	Pritchard.
		0·431	Mean.
76	μ Cassiop.	0·342	O. Struve.
		0·084	Schweizer, *Cat. Stellar Par.*
		0·036	Pritchard.
		0·275	Jacoby, *Annals New York Academy Sc.* vol. viii.
		0·184	Mean.
77	ϵ Indi	0·215	Gill and Elkin, *Mem.* vol. xlviii. p. 187.
78	Cephei 51 (Hev)	0·027	L. de Ball, *Observatory*, vol. viii. p. 314.
79	3077 Bradley	0·205	Backlund, *M.N.* vol. xliii. p. 223.
		0·283	Gyldén, „ „ „
		0·070	Brünnow.
		0·185	Mean.

No.	Star.	Parallax.	Authority.
25	β Aurigæ	0″062	Pritchard.
26	α Androm.	0·058	,,
27	Polaris	0·067	Peters.
		0·025	Schweizer.
		0·015	L. de Ball, *Observatory*, vol. viii. p. 314.
		0·079	Pritchard.
		0·046	Mean.
29	α Arietis	0·080	Pritchard.
31	γ Cassiop.	0·012	,,
32	β Androm.	0·074	,,
35	β Leonis	0·029	,,
37	β Ursæ Min.	0·022	,,
40	γ Cygni	0·102	,,
41	β Cassiop.	0·164	,,
42	α Cassiop.	0·036	,,
43	β Persei	0·058	,,
		0·036	Chase, *Observatory*, vol. xvii. p. 253.
		0·047	Mean.
44	θ Ursæ Maj.	0·080	Pritchard.
45	γ Ursæ Maj.	0·099	,,
46	γ Draconis	0·092	Molyneux, *Nature*, vol. xviii. p. 669.
		0·050	Pritchard.
		0·071	Mean.
47	ε Pegasi	0·080	Pritchard.
48	α Pegasi	0·082	,,
50	α Cephei	0·062	,,
54	ε Cygni	0·128	,,
57	ι Ursæ Maj.	0·133	Peters.
58	θ Ursæ Maj.	0·052	Kapteyn, *Cat. Stellar Par.*
59	α Herculis	0·050	Jacob, *Mem.* vol. xxviii. p. 45.
60	δ Herculis	0·084	Leavenworth, *Cat. Stellar Par.*
61	π Herculis	0·11	Belopolsky, ,, ,, ,,
62	η Cassiop.	0·234	Struve, ,, ,, ,,
		0·257	Schweizer, *M.N.* vol. lv. p. 341.
		0·443	Davis, ,, ,, ,,
		0·311	Mean.
63	η Herculis	0·40	Belopolsky, *Cat. Stellar Par.*
64	10 Ursæ Maj.	0·20	,, ,, ,, ,,

No.	Star.	Parallax.	Authority.
65	70 (*p*) Ophi.	0″·150	Krüger.
		0·286	Schur, *Observatory*, vol. xvii. p. 252.
		0·218	Mean.
66	θ Cassiop.	0·232	Jacoby, *Annals New York Academy of Sciences*, vol. viii.
67	e Eridani	0·136	Elkin, *Mem.* vol. xlviii. p. 178.
68	o^2 Eridani	0·166	Gill, „ „ „ p. 160.
		0·223	A. Hall, *Observatory*, vol. viii. p. 345.
		0·194	Mean.
69	δ Ursæ Min.	0·034	L. de Ball, *Observatory*, vol. viii. p. 314.
70	δ Equulei	0·035	Leavenworth, *Cat. Stellar Par.*
71	σ Draconis	0·246	Brünnow, *Dunsink Obs.* vol. i.
72	ν^2 Draconis	0·28	Belopolsky, *Cat. Stellar Par.*
73	ν^1 Draconis	0·32	„ „ „ „
74	ζ Toucani	0·057	Elkin, *Mem.* vol. xlviii. p. 171.
75	61 Cygni	0·374	Bessel corrected by Peters.
		0·349	Peters, *Cosmos*, vol. iii. p. 260.
		0·505	O. Struve, *Cat. Stellar Par.*
		0·553	Auwers, *M.N.* vol. xxiii. p. 74.
		0·414	Schweizer, *Cat. Stellar Par.*
		0·416	Socoloff, „ „ „
		0·466	Ball, *M.N.* vol. xl. p. 250 and vol. xli. p. 164.
		0·525	Belopolsky, *Cat. Stellar Par.*
		0·270	A. Hall, *Nature*, vol. xxxv. p. 258.
		0·434	Pritchard.
		0·431	Mean.
76	μ Cassiop.	0·342	O. Struve.
		0·084	Schweizer, *Cat. Stellar Par.*
		0·036	Pritchard.
		0·275	Jacoby, *Annals New York Academy Sc.* vol. viii.
		0·184	Mean.
77	ϵ Indi	0·215	Gill and Elkin, *Mem.* vol. xlviii. p. 187.
78	Cephei 51 (Hev)	0·027	L. de Ball, *Observatory*, vol. viii. p. 314.
79	3077 Bradley	0·205	Backlund, *M.N.* vol. xliii. p. 223.
		0·283	Gyldén, „ „ „
		0·070	Brünnow.
		0·185	Mean.

No.	Star.	Huggins. Miles per sec.	Greenwich. Miles per sec.	Potsdam. Miles per sec.	Adopted. Miles per sec.	Adopted. $\frac{dp}{dt}$.
36	ζ Ursæ Maj.	...	+19·3	−19·4	0·0	0?
37	β Ursæ Min.	...	...	+ 8·9	+ 8·9	+ 3
38	α Ophiuchi	...	−10·9	+11·9	+ 0·5	0?
39	α Coronæ	+	+20·7	+19·9	+20·3	+ 7
40	γ Cygni	−	−13·5	− 4·0	− 8·8	− 3
41	β Cassiop.	...	− 1·2	+ 3·2	+ 1·0	0
42	α Cassiop.	...	...	− 9·5	− 9·5	− 3
43	β Persei	...	...	− 1·0	− 1·0	0
44	β Ursæ Maj.	+	+22·9	−18·2	+ 2·4	+ 1?
45	γ Ursæ Maj.	+	+17·5	−16·5	+ 0·5	0?
46	γ Draconis	...	− 7·2	...	− 7·2	− 2
47	ε Pegasi	...	−14·3	+ 5·0	− 4·6	− 2?
48	α Pegasi	−	−25·5	+ 0·8	−12·4	− 4?
49	ε Boötis	−	...	−10·1	−10·1	− 4
50	α Cephei	...	−41·8	...	−41·8	−14
51	β Pegasi	...	...	+ 4·1	+ 4·1	+ 1
52	β Libræ	...	...	− 6·0	− 6·0	− 2
53	α Serpentis	...	...	+14·0	+14·0	+ 5
55	δ Leonis	+	...	− 8·9	− 8·9	− 3
56	β Herculis	...	...	−22·0	−22·0	− 8

Jamaica:
1896 *September.*

On the curve $y = \left\{\frac{1}{x^2 + \sin^2\psi}\right\}^{\frac{3}{2}}$, ***and its connection with an Astronomical Problem.*** By Mrs. W. H. Young (Miss Grace Chisholm).

(*Communicated by Professor G. H. Darwin.*)

Introduction. The Problem and its Origin.

The problem of the determination of the orbit of a comet (or other heavenly body) from three observations leads to the study of the following equation :—

$$m - z = \frac{m}{(1 - 2z\cos\psi + z^2)^{\frac{3}{2}}} = \frac{m}{\lambda^3} \quad \ldots\ldots \quad (1)$$

Here m and ψ are certain constants calculated from the observations ; ψ, being the apparent angular distance between the comet and the Sun, lies between 0° and 180° ; m may have any value, but the sign of m is positive or negative according as the apparent path of the comet is convex or concave toward the Sun.*

The unknown quantity z is the ratio of the geocentric distances of the comet and Sun at the time of the mean observation. Hence we perceive that we wish to determine for z a real positive value. The quantity λ, which is obviously always real, is likewise to be taken positive, for it represents the ratio of the heliocentric distances of the comet and Earth at the time of the mean observation.

If we rationalise the equation by squaring both sides we obtain an equation of the eighth degree in z, which, as such, possesses eight complex solutions, conjugate in pairs. One of these is, however, obviously zero ; hence at least one of the other seven solutions is real. The solution $z = 0$ corresponds to the case where we have been observing, not a heavenly body at all, but a speck in our own atmosphere, or even in the telescope itself ; a mistake which is, theoretically at least, always possible.

We have, then, seven solutions to take into account, of which an odd number ($> 0 \leqq 7$) are real. Possibly no one of these real solutions is positive ; in this case the calculations of m and ψ from the observations, or ultimately the observations themselves,

* $m = \frac{\tau_{,}\tau_{,,,}}{2} \frac{\sin P_{,,}}{\sin p_{,,}} \frac{1}{R_{,,}^3}$,

$P_{,,}$ and $p_{,,}$ being the perpendiculars from the Sun and comet respectively at the time of the mean observation on the great circle through the extreme positions of the comet ; $R_{,,}$ is the distance at the same time of the Earth and Sun ; $\tau_{,}$ is the interval of time between the first and second observations multiplied by Gauss's constant ; and $\tau_{,,,}$ is the same quantity for the second and third observations (Oppolzer p. 362).

are incorrect. But if one single real root be positive then it gives the complete solution of the astronomical problem, and the orbit can be determined. Finally, if more than one real positive solution exists, the observations are insufficient, and the comet must be observed again to discriminate which of the roots is the proper one to take.

We see that the discussion of the roots of the equation (1) has a special interest for astronomers. Now, since the problem as it stands presents difficulties to purely analytical investigation, it was early suggested that it should be treated by geometry, and various geometrical methods have been employed for this purpose. The complete geometrical discussion has not, however, I believe, been given, and I am not aware that the problem has been discussed afresh since the publication of Oppolzer's *Elemente der Bahnbestimmung* (1882). In this last book the geometry is dismissed very shortly, nor is a complete analytical discussion given; and there is one absolute error as to the limits of solution, the detection of which led to the writing of this paper.

The geometrical method which I use differs slightly from Oppolzer's and from that used by any of his predecessors. I have added a note on kindred methods to mine, and the results already obtained by them.

I have only to add that I believe I may offer this as a complete geometrical discussion, and that I have also been enabled in this way to give a simple analytical formula as a criterion for the existence of two roots, corresponding to the old formula for the existence of one root only.

I have added a note on Lambert's curvature theorem and its connection with the geometry.

§ 1. *Notation.*

I shall in this paper use the abbreviations s, c for $\sin\psi$ and $\cos\psi$; s is then always positive, and c is positive or negative according as ψ is less or greater than 90°. We have, however, in all cases

$$s^2+c^2=1, \quad \ldots\ldots\ldots\ldots \quad (2)$$

I then put

$$x=z-c. \quad \ldots\ldots\ldots\ldots \quad (3)$$

and replace the equation (1) by the two equations

$$y=\frac{1}{(x^2+s^2)^{\frac{3}{2}}}=\frac{1}{\lambda^3}, \quad \ldots\ldots\ldots\ldots \quad (4)$$

$$my=m-c-x. \quad \ldots\ldots\ldots\ldots \quad (5)$$

§ 2. *Geometry of the Problem.*

Let us now regard x and y as ordinary Cartesian coordinates, the axis of x being horizontal and that of y vertical. The equation (4) then represents a certain plane curve, the equation (5)

a straight line whose intersections with the curve are the object of investigation.

§ 3. *The Astronomical Point, Critical Point, and Critical Line.*

The point of intersection of the straight line (5) with the curve (4) I call, for obvious reasons, the astronomical point.

The line (5) meets the curve once at the point $(-c, 1)$, which I call the critical point. The vertical line through the critical point I call the critical line: its equation is

$$x + c = 0,$$

or

$$z = 0.$$

The astronomical point, being one for which z is positive, lies to the right of the critical line. Hence we need only consider such intersections of the line (5) with the curve (4) as lie to the right of the critical point.

From the form of the equation we see that $(-m)$ being the cotangent of the inclination of the line to the horizontal axis, m is the distance from the critical line of the point where the line (5) meets the horizontal axis, and is measured to the right if m be positive, to the left if m be negative. This gives a very simple construction for the line (5):

Find the critical point C and draw the vertical line through it. Measure a distance, m (to the right if m be positive, to the left if m be negative), along the horizonal axis, and join the point so found to C: this line is the line (5).

§ 4. *The Geometry of the Curve.*

Remembering that λ is to be a positive quantity, we see that the curve

$$y = \frac{1}{\lambda^3} = \frac{1}{(x^2 + s^2)^{\frac{3}{2}}}$$

lies entirely above the horizontal axis. It is, in fact, only one branch of the algebraic curve of the eighth degree, whose equation is got by rationalising the above equation: this curve possesses a second branch, the reflexion of the first in the horizontal axis, analytically to be distinguished from the upper branch by the fact that in the lower branch λ is always negative. With this lower branch, however, we are not concerned.

Seeing that

$$\frac{dy}{dx} = -3\lambda^{-5}x, \quad \ldots \ldots \quad (6)$$

we recognise that the horizontal axis is an asymptote to our curve, and that there is one other horizontal tangent, at the point M in the figure, where the curve meets the axis of symmetry ($x = 0$). There are no vertical tangents, the steepest inclination being at the inflexions, determined by the equation

$$0 = \frac{d^2y}{dx^2} = 3\lambda^{-7}(4x^2 - s^2),$$

that is to say,

$$x = \pm \frac{s}{2}, \quad \ldots \ldots \ldots \ldots \quad (7)$$

this determines the two inflexions V, W.

Substituting for x in (6), we get the tangent of the angle of inclination of the inflexional tangents given by the expression

$$\frac{3}{2}\left(\frac{4}{5}\right)^{\frac{1}{2}} \frac{1}{s^4}.$$

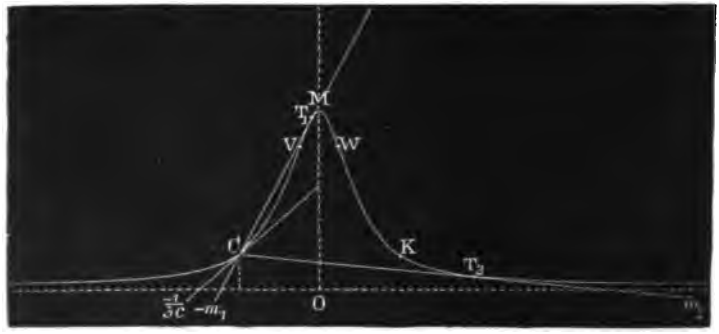


Fig. 1 ($0 < \psi < \tan^{-1} 2$).

Fig. 2 ($\tan^{-1} 2 < \psi < 90°$).

Thus the nearer ψ is to a right angle, the flatter is the curve (see figures). The form of the curve varies otherwise very little with ψ. The only thing which alters materially with ψ is the position of the critical point with respect to the two inflexions. From 0° to 63° 26′ 8″ ($\tan^{-1} 2$,) the critical point lies to the left of both inflexions, as in fig. 1. When $\psi = 63° 26' 8''$ we have

$$c - \frac{1}{2} s = 0,$$

and the critical point coincides with V. Between this value and 116° 33′ 52″ the critical point lies between the inflexions.

Lastly from 116°.33′ 52″ to 180° the critical point lies to the right of both inflexions.

Now inspection of the figures shows us at once, when the curve has been drawn and the critical point C marked on it, how the number of intersections of the line (5) with the curve which lie to the right of C are determined by the inclination of the line, that is, by the value of m. We see at once that there are three important values of m, corresponding to the tangent *at* the critical point, and the two tangents *from* the critical point, these separate values of m, for which there are respectively no solutions, one solution, two solutions of the problem. The first result got by inspection of our figure is the following: *There cannot be more than two solutions of the astronomical problem.*

For it is obvious that the line can in no case intersect the curve in more than three points, one of which is the critical point itself.

§ 5. *Condition for one Solution only.*

Consider first $0° < \psi < 90°$. The figures then show that when m is negative and sufficiently great, there is a single intersection to the right of C. This goes on until the line touches the curve at the critical point. For this line we have

$$m = -\frac{1}{3c},$$

as may be seen by substituting the coordinates of the critical point in the equation (6).

Hence there is one, and only one, solution if, and only if, m be negative and greater in absolute value than $-\frac{1}{3c}$.

If $90° < \psi < 180°$, the critical point lies to the right of the axis of symmetry, and it is obvious that the same conditions hold if we change the sign of m. Both cases are included if we state the condition for the existence of one, and only one, solution to be

$$1 + 3m\cos\psi < 0.$$

§ 6. *Condition for two Solutions.*—Consider first

$$0° < \psi < \tan^{-1} 2,$$

so that the critical point lies to the left of both inflexions, as in fig. 1. Then we see that from C we can draw two tangents to the curve. The first has its point of contact, T_1, between V and M: this tangent, therefore, makes an acute angle with the horizontal axis and corresponds to a negative value, $-m_1$, of m, which is less in absolute value than $\frac{1}{3c}$. The second point of contact T_2 lies beyond W: this tangent has therefore a positive m, say m_2.

Now inspection shows that from $m = -\frac{1}{3c}$ to $m = -m_1$ the

line (5), falling between the tangents at C and T_1, cuts the curve twice to the right of C, the points of intersection falling one to the right, the other to the left of T_1. Hence for such values of m as lie between $-\frac{1}{3c}$ and $-m_1$ there are two solutions.

From $m=-m_1$ to $m=m_2$ the line falls between the tangents at T_1 and T_2, and does not, therefore, cut the curve at all except at the critical point.

For $m=m_2$ to $m=+\infty$, on the other hand, the line obviously cuts the curve twice to the right of the axis of symmetry, and, therefore, there are again two solutions.

Next let

$$\tan^{-1} 2 < \psi < 90°;$$

the critical point C then lies between V and M, as in fig. 2. We see here that the tangent at T_1 has no longer any interest, since the two intersections lie now to the *left* of C.

Thus from $m=-\frac{1}{3c}$ to $m=m_2$ there are no solutions, and from $m=m_2$ to $m=+\infty$ two solutions.

Next let

$$90° < \psi < \tan^{-1}(-2), \text{ (}i.e.\text{ } 116° 33' 52''\text{)};$$

the critical point C then lies between M and W, but the fig. 2 may otherwise serve our purpose. There will then evidently be no solutions from $m=-\infty$ to $m=m_2$, and two solutions from $m=m_2$ to $m=\frac{1}{-3c}$.

Lastly if

$$\tan^{-1}(-2) < \psi < 180°,$$

the critical point lies to the right of both inflexions, and two solutions are not possible for any value of m.

§ 7. *Analytical Criteria for Existence of two Roots.*

From the equation (6) we see that we have m_1 or m_2 according as we substitute the coordinates of T_1 or T_2 in the expression $\frac{\lambda^5}{3x}$.

To find the coordinates of T_1 or T_2 we write down the equation of the tangent at (xy) and make it pass through the critical point $(-c, 1)$.

$$\lambda^5(y-1)+3x(x+c)=0;$$

or, using (4) and substituting for λ^2 its value,

$$\lambda^5 = 4x^2+3cx+s^2.$$

Rationalising this we have to determine x the equation

$$(x^2+s^2)^5=(4x^2+3cx+s^2)^2. \quad \ldots\ldots\ldots \quad (8)$$

One root of this equation is, of course, $x=-c$, corresponding to the tangent at the critical point itself. This root is a double root, and we might, if we chose, divide the whole equation by $(x+c)^2$; this is, however, quite unnecessary, as this root can cause no confusion.

The point of contact T_2 corresponds to the positive root of the equation. When $\psi=116°\ 33'\ 52''$ this root is $\frac{s}{2}$ or $\frac{1}{\sqrt{5}}$ and gradually increases as ψ diminishes, till when $\psi=0$, the root is very nearly 1·8. It may quite easily be calculated from the equation by Horner's method.

The point of contact T_1 corresponds to a negative root which has only to be calculated when $0°<\psi<63°\ 26'\ 8''$, and which is zero when $\psi=0$, and gradually increases up to $\frac{1}{\sqrt{5}}$. In calculating this root for small values of ψ we have to be careful, as there is another root of the equation somewhat greater in absolute magnitude than the one we require, which is also zero when $\psi=0$. This root, however, becomes imaginary for a value of ψ less than $63°\ 26'\ 8''$,* so that with care there ought to be no confusion between the two.

In this way a table may be calculated giving for successive values of ψ the limits within which m must lie in order that there may be one, two, or no solutions of the problem. As follows :—

	m			
ψ	One solution.	Two.	None.	Two.
0 to 63° 26′ 8″	$-\infty$ to $-\frac{1}{3c}$	$-\frac{1}{3c}$ to $-m_1$	$-m_1$ to m_2	m_2 to $+\infty$
63° 26′ 8″ to 90°	$-\infty$ to $-\frac{1}{3c}$		$-\frac{1}{3c}$ to m_2	m_2 to $+\infty$
90° to 116° 33′ 52″	$-\frac{1}{3c}$ to ∞		$-\infty$ to m_2	m_2 to $+\frac{1}{3c}$
116° 33′ 52″ to 180°	$-\frac{1}{3c}$ to ∞		$-\infty$ to $-\frac{1}{3c}$	

The actual numbers are printed in Oppolzer's table XIII., b.

§ 8. *Limits of the Solution* $z\ (=x+c)$.

z being the distance of the astronomical point from the critical line, it is at once evident that, when m is positive, z is less than m. For in this case the astronomical point must lie between the critical point and the intersection of the line (5) with the horizontal axis. When, however, m is negative, it is evident that the

* When the tangent at the left-hand lower inflexion passes through the critical point.

astronomical point must lie in that part of the curve which lies between the critical point C and its reflexion K in the axis of symmetry. Hence when m is negative $z < 2c$. This inequality is, I believe, new, though it is perfectly obvious from Lambert's curvature theorem without reference to the curve. I give it here chiefly because Oppolzer makes a misstatement on this point when he says that, m being negative, z may have any value from 0 to ∞. This mistake has not, however, crept into his tables.

§ 9. *Note on Lambert's Curvature Theorem.*

Let us imagine the Sun to be at the origin of coordinates O. Now when m is negative, the astronomical point must lie in that part of the curve which lies between the critical point C and its reflexion K in the axis of symmetry, *i.e.* in that part of the curve which is concave toward the Sun, like the apparent path of the comet in this case.

Similarly when m is positive the astronomical point must fall beyond the two points C, K, and therefore in the part of the curve which is convex toward the Sun like the apparent path of the comet in this case. This serves as an easy *memoria technica* for the relation between the sign of m and the concavity or convexity of the apparent path.

Further, since between C and K, λ is less than unity, being equal to unity at C and at K, and greater than unity beyond C and K, it follows that when m is positive the astronomical point has its λ greater than unity, and when m is negative less than unity.

Remembering that for the astronomical point, λ is the ratio of the heliocentric distances of the comet and Earth, this gives us at once Lambert's curvature theorem, viz. *the comet is nearer the Sun than the Earth is if the apparent path be concave toward the Sun, but is further away than the Earth if it be convex.* The figure is again a great help to the memory.

§ 10. *Note on Geometrical Discussions of the Problem.*

In Gauss's *Theoria Motus*, edited by C. H. Davis, Boston, 1857, references will be found, and abstracts of all the papers on the subject which had appeared up to that date. Of these Encke's original paper on the subject (1848) appears to be the fullest. The curves used by him are, however, complicated, since he treats the equation in the form

$$m \sin 4z = \sin (z - q).$$

Several methods by means of a straight line and curve are given in the book referred to. In all of them, however, the construction of the straight line is made to depend on both

parameters (m, ψ), while the curve is fixed independently. That which has most resemblance to my method is M. Binet's in the *Journal de l'École Polytechnique*, 20 cahier, tome xiii. p. 285. He uses the fixed curve

$$y = \frac{1}{(1+x^2)^{\frac{1}{2}}}.$$

The discussion is, however, very short, and aims only at showing that more than two solutions are impossible, and at obtaining the criterion for a single root. Many years later (1882) Oppolzer used the curve

$$y = \frac{m}{\{1 - 2x\cos\psi + x^2\}^{\frac{1}{2}}}$$

to prove only that more than two solutions are impossible. Here the straight line being inclined at 135° to the axis of z is fixed in direction, and therefore easy to construct, but the discussion is made difficult by the presence of both parameters in the equation to the curve. Oppolzer indeed not only dismisses the geometry very shortly, but gives in his book no general theory, or even an explanation of the mode in which his tables were constructed.

In my own treatment of the subject I have aimed at keeping the two parameters (m, ψ) geometrically distinct, so as to simplify the theory and the classification of the different cases.

Cambridge: March 2, 1897.

On the Orbit of the November Meteors. By Prof. J. C. Adams.*

It is known to the President and to several members of the Society that I have been for some time past engaged in researches respecting the November Meteors, and allusion is made to some of my earlier results in the last Annual Report. As my investigations are now in some measure complete, and the results which I have obtained appear to me important, I have thought that they may not be without interest for the Society.

In a memoir on the November Star Showers, by Professor H. A. Newton, contained in Nos. 111 and 112 of the *American Journal of Science and Arts*, the author has collected and discussed the original accounts of 13 displays of the above phenomenon in years ranging from A.D. 902 to 1833.

The following table exhibits the dates of these displays, and the Earth's longitude at each date, together with the same particulars for the shower of November last, which have been added for the sake of completeness.

* This paper, by the late Professor Adams, originally appeared in *Monthly Notices*, vol. xxvii. p. 247 (1867 April), but there are now not many copies of the number left in stock. Applications for copies have already been made to the Council, and in view of the return of the *Leonids* in the next few years they have determined to reprint the paper in the current number.—Eds. *M.N.*

No.	A.D.	Day and hour. d h		Earth's longitude. ° ′
1	902	Oct. 12 17		24 17
2	931	14 10		25 57
3	934	13 17		25 32
4	1002	14 10		26 45
5	1101	16 17		30 2
6	1202	18 14		32 25
7	1366	22 17		37 48
8	1533	24 14		41 12
9	1602	27 10	O.S.	44 19
10	1698	Nov. 8 17	N.S.	47 21
11	1799	11 21		50 2
12	1832	12 16		50 49
13	1833	12 22		50 49
14	1866	13 13		51 28

From these data Professor Newton infers that these displays recur in cycles of 33·25 years, and that during a period of two or three years at the end of each cycle a meteoric shower may be expected. He concludes that the most natural explanation of these phenomena is, that the November Meteors belong to a system of small bodies describing an elliptic orbit about the Sun, and extending in the form of a stream along an arc of that orbit which is of such a length that the whole stream occupies about one-tenth or one-fifteenth of the periodic time in passing any particular point. He shows that in one year the group must describe either $2 \pm \frac{1}{33 \cdot 25}$, or $1 \pm \frac{1}{33 \cdot 25}$, or $\frac{1}{33 \cdot 25}$ revolutions, or, in other words, that the periodic time must be either 180·0 days, 185·4 days, 354·6 days, 376·6 days, or 33·25 years.

It is seen that the time of the year at which the meteoric shower takes place becomes gradually later and later, and that accordingly the Earth's longitude at that time, or the longitude of the node of the orbit of the meteors, is gradually increasing. Professor Newton finds that the node has a mean motion of 102″·6 annually with respect to the Equinox, or of 52″·4 with respect to the fixed stars; and he remarks that since the periodic time is limited to five possible values, each capable of an accurate determination, and since therefore from the position of the radiant point the other elements of the orbit can be found, it seems possible to compute the secular motion of the node for each periodic time with considerable accuracy; and the actual motion of the node being known, we have thus an apparently simple method of deciding which of the five periods is the correct one.

Soon after the remarkable display of these meteors in November last, I undertook the examination of this question.

From the position of the radiant point as observed by myself, I calculated the elements of the orbit of the meteors, starting with the supposition that the periodic time was 354·6 days, the value which Professor Newton considered to be the most probable one. The orbit which corresponds to this period is very nearly circular, and it readily follows from the ordinary theory that the action of *Venus* would produce an annual increase of about 5″ in the longitude of the node, and that of *Jupiter* an annual increase of about 6″. The calculation of the motion of the node due to the Earth's action presented greater difficulty in consequence of the two orbits nearly intersecting each other. I succeeded, however, in obtaining an approximate solution, applicable to this case, from which it followed that the Earth's action would produce an annual increase of nearly 10″ in the longitude of the node. Thus the three planets above mentioned, which alone, in the case supposed, sensibly affect the motion of the node, would cause a motion of about 21″ annually, or nearly 12′ in 33·25 years. It has been already mentioned that the observed motion of the node is 52″·4 annually, or about 29′ in 33·25 years. Hence the observed motion of the node is totally irreconcilable with the supposition that the periodic time of the meteors about the Sun is 354·6 days. If the periodic time were supposed to be about 377 days, the calculated motion of the node would differ very little from that in the case already considered; while, if the periodic time were a little greater or a little less than half a year, the calculated motion of the node would be still smaller. Hence, of the five possible periods indicated by Professor Newton, four are entirely incompatible with the observed motion of the node; and it only remains to examine whether the fifth period, viz. one of 33·25 years, will give a motion of the node in accordance with observation.

The calculations which have been above described were entirely founded on my own determination of the radiant point. In order to have as secure a basis as possible for the subsequent calculations, I adopted for the position of the radiant point the mean of my own and five other determinations, partly taken from published documents and partly privately communicated to me. These determinations are as follows, the several authorities being placed in alphabetical order:—

	R.A.	Decl.
	° ′	° ′
Adams	148 50	22 10 N.
Baxendell	149 33	22 57
Brünnow	150	22
Challis	149 39	23 12
Herschel	148 9	23 48
Herschel, A.	149	24
Mean	149 12	23 1 N.

Or with reference to the ecliptic,

Long. 143° 22′ Lat. 9° 51′ N.

Starting from this position of the radiant point, and the assumed period, and taking into account the action of the Earth on the meteors as they were approaching it, I obtained the following elliptic elements of their orbit :—

Period	33·25 years (assumed)
Mean distance	10·3402
Excentricity	0·9047
Perihelion distance	0·9855
Inclination	16° 46′
Longitude of Node...	51 28
Distance of Perihelion from Node	6 51
Motion Retrograde	

In order to determine the secular motion of the node in this orbit, I employed the method given by Gauss in his beautiful investigation "*Determinatio attractionis &c.*"

It may be proved that if two planets revolve about the Sun in periodic times which are incommensurable with each other, the secular variations which either of these bodies produces in the elements of the orbit of the other would be the same as if the whole mass of the disturbing body had been distributed over its orbit in such a manner that the portion of the mass distributed over any given arc should be always proportional to the time which the body takes to describe that arc. In the memoir just referred to Gauss shows how to determine the attraction of such an elliptic ring on a point in any given position. When this attraction has been calculated for any point in the orbit of the meteors, we can at once deduce the changes which it would produce in the elements of the orbit, while the meteors are describing any given small arc contiguous to the given point. Hence, by dividing the orbit of the meteors into a number of small portions, and summing up the changes corresponding to these portions, we may find the total secular changes of the elements produced in a complete period of the meteors.

In this manner I have found that during a period of 33·25 years, the longitude of the node is increased 20′ by the action of *Jupiter*, nearly 7′ by the action of *Saturn*, and about 1′ by that of *Uranus*. The other planets produce scarcely any sensible effects, so that the entire calculated increase of the longitude of the node in the above-mentioned period is about 28′.

As already stated, the observed increase of longitude in the same time is 29′. This remarkable accordance between the results of theory and observation appears to me to leave no doubt as to the correctness of the period of 33·25 years.

In order to attain a sufficient degree of approximation it is requisite to break up the orbit of the meteors into a considerable number of portions, for each of which the attractions of the elliptic rings corresponding to the several disturbing planets have to be determined; hence the calculations are necessarily very long, although I have devised a modification of Gauss's formulæ which greatly facilitates their application to the present problem. In these numerical calculations I have been greatly aided by my assistants, more especially by Mr. Graham. I am now engaged in obtaining a closer approximation by subdividing certain parts of the orbit of the meteors into still smaller portions, but the results which have been given above cannot be materially changed.

Since I entered upon the foregoing investigation other astronomers have been led, on totally independent grounds, to conclusions which strongly confirm, and are confirmed by, those at which I have myself arrived.

In the *Bullettino Meteorologico dell' Osservatorio del Collegio Romano*, vol. v. Nos. 8, 10, 11, 12, are published four letters from Sig. Schiaparelli, Director of the Observatory of Milan, "*Intorno al corso ed all' origine probabile delle Stelle Meteoriche.*" In these letters the author arrives at the conclusion that the orbits which the meteors describe about the Sun are very elongated, like those of comets, and that probably both these classes of bodies originally come into our system from very distant regions of space. In his last letter, dated 31st December 1866, Sig. Schiaparelli shows that if the August Meteors be supposed to describe a parabola, or a very elongated ellipse, the elements of their orbit, calculated from the observed position of their radiant point, agree very closely with those of the orbit of Comet II. 1862, calculated by Dr Oppolzer. The following table exhibits this agreement :—

	August Meteors.	Comet II. 1862.
Perihelion distance	0·9643	0·9626
Inclination	64° 3′	66° 25′
Longitude of Perihelion	343 28	344 41
Longitude of Node	138 16	137 27
Direction of Motion	Retrograde	Retrograde

Hence it appears probable that the great Comet of 1862 is a part of the same current of matter as that to which the August Meteors belong.

In the letter which has just been referred to Sig. Schiaparelli likewise gives approximate elements of the orbit of the November Meteors, calculated on the supposition that the period is 33·25 years; but as the calculations were founded on an imperfect determination of the radiant point, these elements were not sufficiently accurate, and Sig. Schiaparelli failed to find any

cometary orbit which could be identified with that of the meteors.

Soon after this, on the 21st January 1867, M. Le Verrier communicated to the Academy of Sciences a theory of the origin and nature of shooting stars, very similar in its main features to that of Sig. Schiaparelli, and at the same time gave more accurate elements of the orbit of the November Meteors, his calculations being based on a better determination of the radiant point than that employed by the astronomer of Milan.

In the *Astronomische Nachrichten* of the 29th January Mr. C. F. W. Peters, of Altona, pointed out that the elements given by M. Le Verrier closely agreed with those of Tempel's Comet (I. 1866), calculated by Dr. Oppolzer, and on the 2nd February, Sig. Schiaparelli, having recalculated the elements of the orbit of the meteors on better data than before, himself noticed the same agreement.*

Dr. Oppolzer's elements of Tempel's Comet are as follows :—

Period	33·18 years
Mean distance	10·3248
Excentricity	0·9054
Perihelion distance	0·9765
Inclination	17° 18′
Longitude of Node	51 26
Distance of Perihelion from Node	9 2
Direction of Motion	Retrograde

If these elements be compared with those of the November Meteors which I have given in a former part of this communication, it will be seen that their agreement is remarkably close.

The curious and unexpected resemblance which is thus shown to exist between the orbits of known comets and those of the meteors, both of August and November, opens a wide field for speculation. It is difficult to believe that the coincidences which have been noticed are merely accidental ; but whether or not we are disposed to adopt the ideas of Sig. Schiaparelli as to the intimate relations between meteors and comets, I cannot help thinking that my researches respecting the motion of the node of the November Meteors have settled the question as to the periodic time of these bodies beyond a doubt.

* In the original paper the footnote to this asterisk stands. See ante, p. 246— ED., giving the reference to the following note on Schiaparelli's work :—

In the *Ast. Nach.* No. 1629, is contained a paper by Prof. Schiaparelli, "Sur la Relation qui existe entre les Comètes et les Etoiles filantes."

After referring to his letters to Padre Secchi published in the Bulletins of the Observatory of Rome, he reproduces the results as to the August meteor, see *Monthly Notices*, pp. 133–134. He remarks: "In the writings referred to, the position of the Radiant Point of the November Meteors had been taken as the point determined by the American observations of 1833, viz. γ *Leonis*, which is erroneous by several degrees. The new calculation, compared with Dr. Oppolzer's elements of the comet *Ast. Nach.* 1624, the perihelion passage being reduced to Milan Mean Time, is—

	Meteors, 13th Nov.	Comet I, 1866.
Perihelion passage	Nov. 10, 092	Jan. 11, 160
Longitude of Perihelion ...	56°25′ 9″	60°28′ 0″
Node	231 28 2	231 26 1
Inclination	17 44 5	17 18 1
Perihelion distance ...	0·9873	0·9705
Excentricity	0·9046	0 9054
Semi-axis major ...	10·340	10·324
Revolution	33·250 years	33·176
Motion	retrograde	retrograde

where it is assumed, 1°, the time of max. of the meteors is Nov. 13 $13^h\ 11^m$ Greenwich M.T.; 2°, the position of the radiant point, long. 143° 12′, lat. N. 10° 16′; 3°, period 33·25 years (Newton). The position of the radiant point is that determined by Mr. Herschel, *Monthly Notices*, vol. xxvii. p. 19; but taking the longitude 145° instead of 143° 12′, the discrepancy of 4° in the longitude of perihelion would be made to disappear." M. Schiaparelli asks, Are the meteors to be considered as swarms of minute comets, or as the products of the dissolution of large comets?

— —

Orbit of 44 *Boötis* (H I. 15=Sh 193=Σ 1909).

By S. W. Burnham.

As a double star this was discovered by Herschel August 17, 1781, and the position-angle by a single measure recorded at that time as 29°·9 *nf*, which, according to the mode of reckoning then in use, would give 60°·1. The distance was estimated to be "one-half or three-fourths diameter of S [smaller star]." It does not appear to have been looked at again by Herschel until 1802·25, when, according to his MS. observations, he made the angle 27° *sp* (=243°). These observations are cited in the Catalogue of Herschel II. and South (*Phil. Trans.* 1824), and

also a later note in the MS. of Herschel I., under date of 1803·19, in which it is stated, "the position is not *sp*, as marked in the last observation [1802·25], but *nf*. Distance, one-half diameter of S″. This correction would change the angle of that time from 243° to 63°, and thus apparently show little or no change in the twenty years preceding. From the description the distance would appear to be a little less than at the first observation. The angle was measured by Struve in 1819, and the distance estimated at 1″·5. The next published observation is found in the Catalogue of Herschel and South, who entered it as No. 193 of their list, and measured it on two nights in 1821. They remarked the non-agreement of their angle (229°·1) with the previous measures of Herschel I., and said, "The identity of this star with H I. 15 may be questioned, as it is not impossible that there may be another double star of the first class near the same place with which it has occasionally been confounded. If not, or unless one or both of the stars be variable in magnitude, it is not easy to reconcile the observations." They also compare their position with that of Struve in 1819, and conclude that there can be no rapid motion, as had been suggested by that observer. Struve's observations were resumed in 1826, and show a steady increase in the distance from that time to 1837, with a slight advance in the angle.

Herschel in 1831 (*Mem. R.A.S.*, vol. xlvi.), after giving the measures down to 1830, says :—

"The history of the star 44 *Boötis* is singularly beset with difficulties and apparent contradictions. It is true that an orbit passing nearly through the eye, and so situated that the longer axis of the ellipse into which it is projected shall form an angle of about 6° with the meridian, would account for the remarkable jump the small star seems to have made from one side to the other of the large one ; for its very slow motion between 1781 and 1802 (especially if we admit some conspiring errors in those angles), and for its moderate velocity at present, but a year or two more of observations will probably suffice to render present conjecture needless."

It is probable that the angle of 6° mentioned in this extract is a misprint for 60°, which corresponds to the general apparent movement of the companion. A writer in *Nature* (vol. xiii. 69), in a note on Doberck's orbit, then recently published, suggests that the angle of Herschel in 1802 should not be 63°, as now taken upon the authority of Herschel's MS. correction (making the observation 27° *nf*, instead of 27° *sp* as at first given), but 207° (180°+27°), and points out that with this correction it agrees perfectly with the position of the star in 1802, according to Doberck's orbit. He says :—

"It is now pretty evident from a projection of all the measures to 1875 that the quadrant was correctly registered *sp*, and consequently the quadrant for 1802·24 should be 207°, according to our present mode of reckoning. The angle calculated for this

time from the above orbit is 206° 55′, and this close agreement must be taken as very satisfactory evidence that Dr. Doberck has given us something like the true orbit, notwithstanding the difficulty of the case."

In a subsequent reference to this matter (*Observatory* II. 210), Doberck refers to the suggested correction and its agreement with his orbit, and explains why he rejected in his computation Herschel's position of 63° for 1802, and relied only upon that for 1781.

But these astronomers have overlooked the important fact that under no circumstances could the suggested position-angle be correct. At this time all readings of the micrometer were invariably reckoned from the parallel, that is, added to or subtracted from 270° or 90°, as the case might be. If Herschel inadvertently recorded the angle of the larger instead of the smaller star, or in other words made an error of 180°, and entered it as 27° *sp* instead of *nf*, the true angle would be 243° (270°−27°) instead of 63° (90°−27°), but it could not possibly be 207° (180°+27°) any more than it could be 360°−27°. Such a method of reckoning was never used by Herschel or any one else.

It is possible that Herschel's angles of 1781 and 1802, placing the smaller star in the first quadrant, and in nearly the same direction from the principal star, are substantially correct. There may have been a decided change in the distance during that interval, by a separation and a subsequent approach of the stars, which would not have shown at the time of his observations, even if the distance had been measured. At this time we know absolutely nothing of the form of the apparent orbit, and until this is made to appear with reasonable certainty from the measures which commence with Struve, we cannot safely make any use of the observations prior to that time.

Flammarion in 1878 (*Catalogue des Étoiles Doubles et Multiples*) mentioned the nearly rectilinear motion of the companion, and came to the conclusion that the maximum distance had been reached, and that the companion would then commence to retrace its path towards the primary. He thought that an occultation must have taken place at the beginning of this century, and that this phenomenon would recur on the other side of the orbit about the year 1945; and that if the oscillation of the companion with respect to A was symmetrical, the period should be about 280 years.

Two orbits have been computed of this system:

1852	Mädler	181 years	Dorp. Obsns. xiii.
1875	Doberck	261·12 „	A.N. 2064.

The years given above indicate the dates of the last measures used by the respective computers.

It is certainly evident now that there was nothing at these times upon which to base a determination of the periodic time, or the form of the apparent orbit, even if the position of Herschel in 1781 was correct. While the position in the first quadrant might limit the ellipse on the following side, the subsequent measures could not in any manner indicate the extent of the ellipse in the opposite direction, and the period might be anything the computer saw fit to make it. It is hardly necessary to add that the same uncertainty exists at the present time, and so far as one can judge from all the measures, it will be a long time, possibly another hundred years, before a sufficient arc will be passed over to warrant any attempt to investigate the elements of the orbit. The total angular motion during the time covered by the reliable measures is not more than 13°, and the apparent change is nearly rectilinear. There is certainly no doubt that these stars constitute a physical system, and are likely to be hereafter of more than ordinary interest. The components have a considerable common proper motion. The latest determination by Porter gives an annual movement of 0″·401 in the direction of 276°·0.

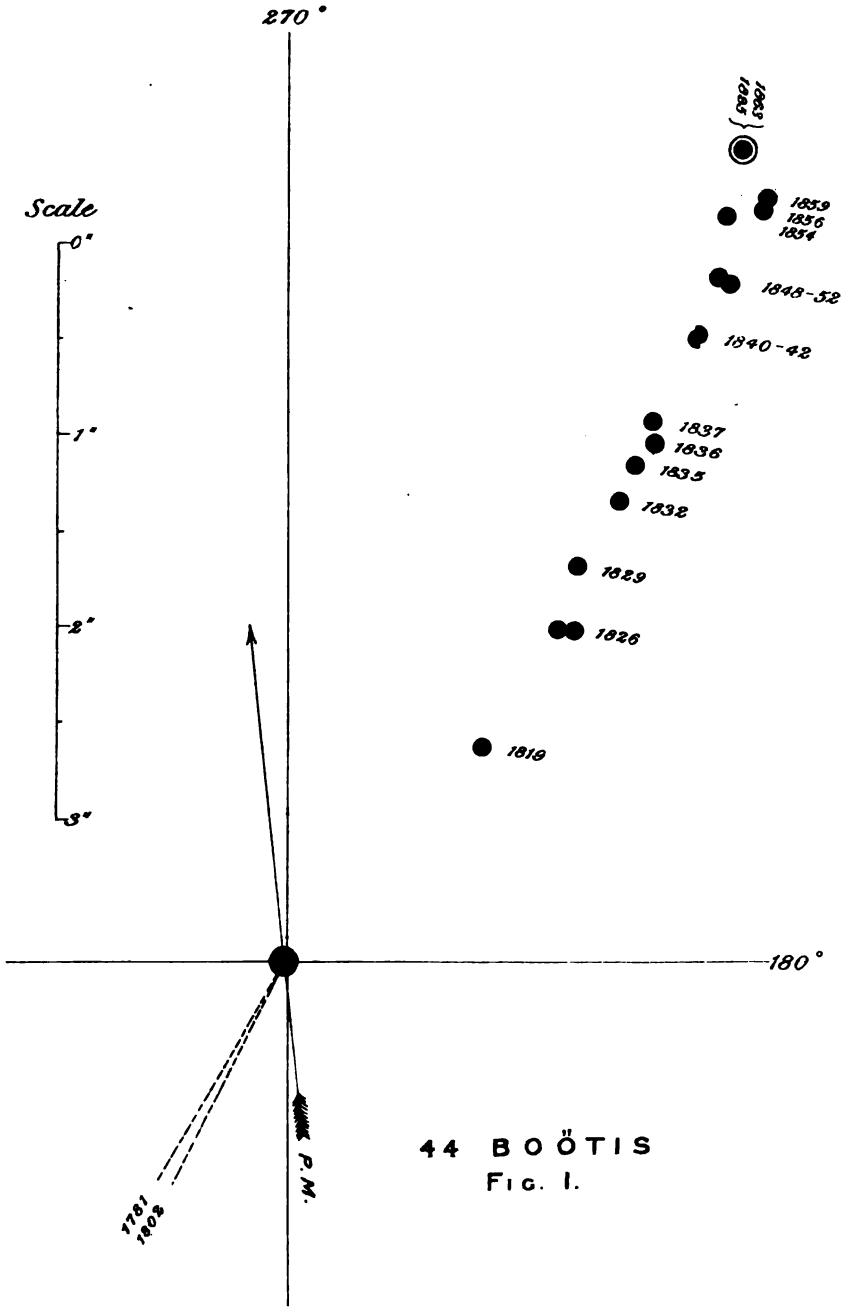
In fig. 1 I have given the early measures by the leading and best observers, laid down to scale in the usual way. These fifteen positions are made up as follows :—

1819	Σ		1848	OΣ and Da	6n
1821	Sh	2n	1852	Ma	30n
1826–1837	Σ (6)	20n	1854	Δ	13n
1840	OΣ and Da	14n	1856	OΣ and Δ	9n
1842	OΣ and Da	10n	1859·5	Ma and Δ	10n

The last position on the diagram shown by the larger circle is from the mean result of 26 sets of measures from 1863 to 1895. These measures include altogether observations on 108 nights by the following observers :—

O. Struve	12n	Hall	32n
Dembowski	18n	Comstock	5n
Schiaparelli	37n	Maw	2n
	Collins	2n	

In fig. 2 all the individual sets of measures above referred to are laid down on square-ruled paper in order to show more clearly the changes in angle and distance at the corresponding dates shown on the lower line of the diagram. It is apparent from inspection that there has been no sensible change in the distance since 1860. There may have been a slight increase in the angle for a short time after this date, but it is by no means certain. We may assume that for the last thirty years these stars have remained relatively fixed so far as the measures are concerned.



44 BOÖTIS
FIG. I.

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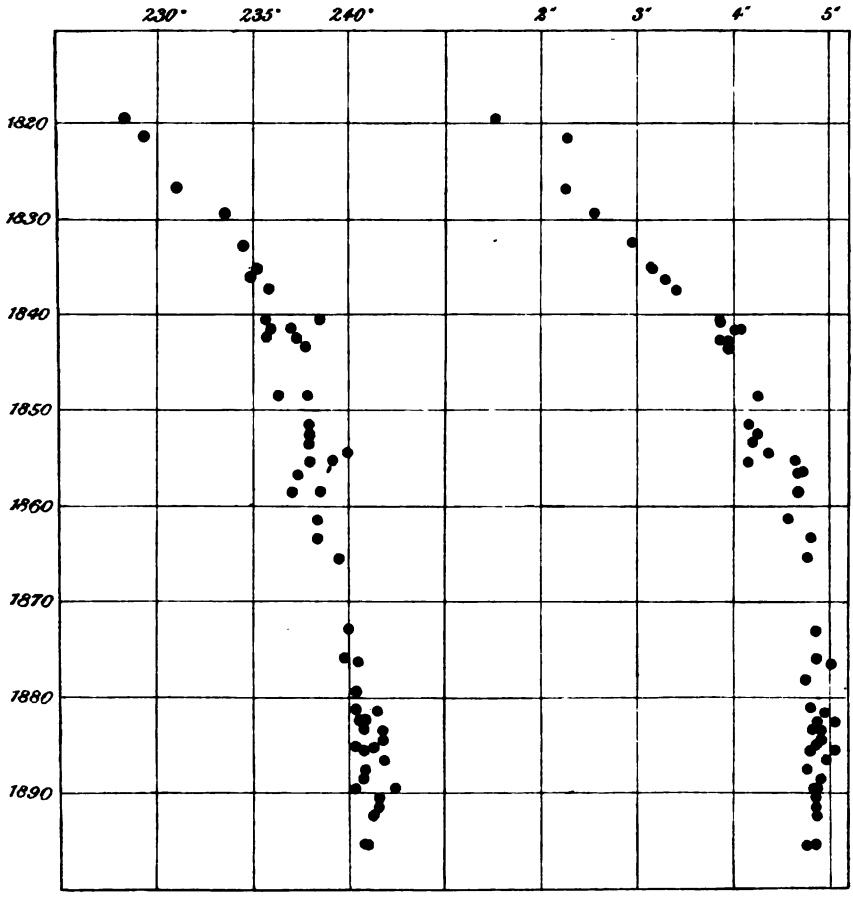
44 BOÖTIS

FIG. 2.



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In the following table I have given the variations of the several sets of measures made between 1863 and 1895 from the two means, one of all the measures between these years, and the other of the measures from 1881 to 1895. It will be seen that these variations are practically insensible, and less or no larger than the probable error of any observer when his results are compared one with another.

	1863—1895.		1881—1895.		
	°	″	°	″	
1863·44	−2·5	−0·04	...	...	OΣ
1865·36	−1·3	−0·08	...	...	Δ
1873·00	−0·7	+0·03	...	...	Δ
1876·10	−1·1	+0·02	...	...	Sp.
1876·47	−0·3	+0·19	...	...	Hl.
1879·18	−0·4	−0·08	...	...	Sp.
1881·11	−0·4	−0·04	−0·7	−0·07	Sp.
1881·40	+0·5	+0·10	+0·4	+0·07	Hl.
1882·41	+0·2	+0·21	−0·1	+0·18	Hl.
1882·50	−0·2	+0·04	−0·5	+0·01	Sp.
1883·47	+0·9	+0·08	+0·6	+0·05	Hl.
1883·47	+0·2	−0·01	−0·5	−0·04	Sp.
1884·44	+0·8	+0·09	+0·5	+0·06	Hl.
1884·97	−0·5	+0·04	−0·8	+0·01	OΣ
1885·38	+0·4	+0·20	+0·1	+0·17	Hl.
1885·46	−0·1	−0·03	−0·4	−0·07	Sp.
1886·43	+1·1	+0·12	+0·8	+0·09	Hl.
1887·57	+0·2	−0·08	−0·1	−0·11	Sp.
1888·42	+0·1	+0·07	−0·2	+0·04	Hl.
1889·51	+1·7	−0·04	+1·3	−0·07	Hl.
1889·61	−0·5	+0·01	−0·8	−0·02	Maw
1890·48	+0·8	+0·01	+0·5	−0·02	Hl.
1891·45	+0·7	+0·03	+0·4	0·00	Hl.
1892.58	+0·5	+0·01	+0·2	−0·02	Com.
1895·43	+0·2	+0·03	−0·1	0·00	Col.
1895·49	+0·3	−0·11	0·0	−0·14	Com.

The special object of this paper is not to point out the unwarranted conclusions reached heretofore respecting this star as a binary system, but to call attention to the singular and remarkable arrest of the relative motion of the two stars. For more than thirty years these stars gradually increased their distance from 1″·5 to about 4″·8 at a nearly uniform rate, with a slow advance in the angle; and then all motion is arrested, and

for a like period of about thirty years, and down to the present time they have remained absolutely at rest so far as one can tell from full and careful sets of measures by the best double star observers. So far as I know, there is no other instance of this kind known in the heavens. There is no lack of examples of double stars where the motion as shown by the various measures is apparently peculiar, and possibly inconsistent with the theory of the mutual attraction of the observed bodies; and various speculations have been advanced to explain the so-called irregular variable motions. A dark or invisible star is usually interposed to account for the observed movements. With all the latitude afforded by the unavoidable errors of observation, which very often appear to assume a systematic form, it is not difficult in any instance to suggest an undiscovered disturbing body which, according to the terms of the proposed hypothesis, shall appear to more or less perfectly account for the observations, but in most instances the disturbing body is more likely to be finally discovered at the smaller end of the telescope than elsewhere.

With respect to this star, I have only to add that it seems to furnish an example, perhaps the only one, of so peculiar motion that the explanation is not readily suggested by the observations themselves. The steady change in the position of the smaller star for about forty years, and the subsequent arrest of its motion, which has continued down to the present time, are both apparently established by unimpeachable observations by the best observers. Of course any attempted explanation at this time would be premature, at the best only speculation, and would have no value, and presumably no interest. The usual dark body will readily suggest itself, and it is easy to imagine one of these stars having an invisible companion, the two moving in a very eccentric orbit, the plane of which is nearly in the line of sight, and to select a period and direction of motion for the hypothetical pair such as will explain approximately not only the motion, but the absence of motion, shown by the observations of the invisible components; and when this is presented with the usual refinements of computation, doubtless for the time being a plausible case could be made out. When the relative motion has been resumed, and a decided change has taken place, there may be no difficulty in determinining with substantial accuracy the general form of the orbit, and explaining the apparent anomalous relative movement of these stars, without assuming the existence of any third member of the system.

On a New Binary of Short Period in the Constellation Dorado $=H_2$ 3683. By T. J. J. See, A.M., Ph.D. (Berlin).

While sweeping over some of the brighter stars in the constellation *Dorado*, January 14, I recognised the duplicity of a yellow star of the 6·5 magnitude; under a power of 520 the components were just well separated, and in brightness rated at

7·8 and 8. This star has proved to be No. 1583 in the Catalogue of Lacaille, by whom it was first observed. In the *Argentine General Catalogue* it is numbered 5325, the companion 5326. The position of the principal star referred to 1900·0 is

$$\alpha = 4^h\ 38^m\ 39^s{\cdot}3;\quad \delta = -59^\circ\ 8'\ 32''{\cdot}8.$$

While sweeping with the 20-foot reflector at the Cape of Good Hope, 1834 December 3, Sir John Herschel discovered that the star is a fine double. His observations of it are—

(1) *With the 20-foot Reflector.*

t	θ_o	ρ_o	
1834·920	260°·8*	3″	± very fine.
1836·030	261·5*	3	± very fine, but ill-defined.
1835·475	261·1	3	± 2n Herschel.

(2) *With the 7-inch Equatorial.*

t	θ_o	ρ_o	
1835·925	82°·5	3″·25	
1836·884	80·0	4·20	glimmering, but perfectly steady.
1836·404	81·2	3·72	2n Herschel.

The next determinations of the places of the two components are those made at Cordoba by Gould, who gives the following positions :—

		Mag.	Mean Epoch.	α h m s	δ ° ′ ″	No. of Obs.	
5325	Dorado	7	74·82	4 38 14·71	−59 11 24·5	6−6	
5326	Dorado	7¾	73·94	4 38 14·99	−59 11 23·9	1−1	comes sq.
			74·99	15·11	23·5	5−5	

Reduced to polar coordinates these differences in R.A. and Decl. give

t	θ_o	ρ_o	
1874·38	74°·4	2″·23	1n
1874·90	71·5	3·16	5n

where the mean dates have been used.

If we assign to each result weight proportional to the number of nights we shall obtain

t	θ_o	ρ_o	
1874·82	72°·0	3″·00	6n Gould.

While the errors of positions depending on the Meridian Circle are not so small as those of good micrometer measures, there is no doubt that this place fairly represents the position of the companion at the epoch 1874·82.

* These angles should be diminished by 180°.

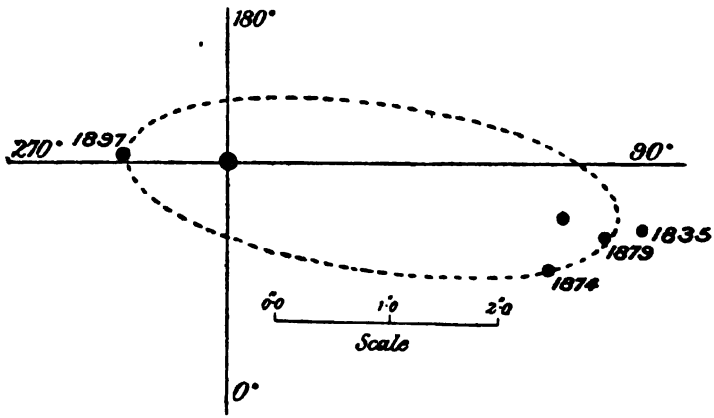
Apparently the only other previous measures of this system are those made by Russell and Hargrave at Sydney in 1879. Their settings of the micrometer gave

t	θ_0	ρ_0	
	°	″	
1879·096	79·1	3·46	1*n* Russell.
1879·096	80·6	3·32	1*n* Hargrave.
1879·096	79·3	3·39	2*n*

Our measures with the 24-inch Clark refractor are as follows :—*

t	θ_0	ρ_0	
	°	″	
1897·036	265·1	0·87	
1897 068	267·0	0·85	
1897·071	263·1	1·03	
1897·058	265·1	0·92	3*n* See.
1897·068	257·7	—	
1897·071	261·3	1·0 ±	
1897·070	259·5	1·0 ±	2–1*n* Cogshall.

On comparing this place with that given by Gould in 1874 we see that a great change has taken place in the last twenty-two years; indeed, the change since 1879 has been almost as noticeable. It is now clear that when Russell made his measure eighteen years ago the companion was in almost exactly the same place observed by Herschel in 1835, and hence the period is



* Difficult on account of low altitude.

approximately forty-four years. Since it is certain that we may rely on the general accuracy of Gould's place for 1874, it is evident that the motion is direct. From the present position of the companion it is clear that the previous observations relate to the apastron part of the apparent orbit. We may also infer that the eccentricity will lie between 0·6 and 0·7, and that the orbit is considerably inclined about a line of nodes near 85°. The observations do not suffice to fix the other elements, but we may conclude that the apparent orbit will not be very different from that indicated in the figure. The approximate period is obtained by comparing the observations of Herschel and Russell; the constant of areas by comparing the places of Gould and Russell; and hence it is possible to fix the area included between 1879 and 1897. Although the slope of the included arc cannot yet be determined, the approximate path here sketched will be useful to observers.

The rapid motion of this system, which has already carried the companion through one and a half revolutions, combined with the wide angular separation of the components and the high eccentricity of the orbit, renders it an object of extraordinary interest; and hence it merits the most careful attention of observers in the southern hemisphere.

Lowell Observatory, City of Mexico:
1897 *January* 28.

Estimations of the Magnitude of Nova Aurigæ made at the Radcliffe Observatory, Oxford. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

In the *Monthly Notices* for 1892 April estimations of the magnitude of *Nova Aurigæ* from 1892 February 3 to March 31 are given. In that interval the star was observed to change from mag. 4·4 to 14·0, the limit of visibility of the Radcliffe instrument. A chart is also given of the comparison stars with their adopted magnitudes.

Subsequent notes in the *Monthly Notices* for 1892 Nov., 1893 Jan., and 1895 Jan. reported that estimations had been made at intervals during 1892, 1893, and 1894; but on the nights, whose dates are there given, the star remained at about 9·7 on the adopted scale.

Since these printed reports examinations have been made on 1895 January 23, 30; September 26; December 7, when no change from 9·7 was detected.

But on 1897 March 10 another examination at once revealed a considerable diminution in brightness; and comparisons made independently by two observers, Mr. Robinson and Mr. McClellan, give the magnitude of the *Nova* as 11·3 on the scale previously adopted. Mr. McClellan also remarked that there

were flickering fluctuations in the brightness of the *Nova*, as seen in previous years, which were not noticed in the comparison stars.

On March 12 the magnitude was estimated by Mr. Wickham as 11·6.

Further Proof of the Rotation Period of Venus.

By Percival Lowell.

(*Communicated by the Secretaries.*)

As the importance of the rotation period of the planet *Venus* is fundamental to the physical constitution of that planet's surface, and as the observations here are absolutely conclusive to the effect that the planet rotates once in an orbital revolution, I send the Society a fresh piece of evidence in the matter which to a certain class of minds is likely to have more weight than any number of drawings.

Drawings are not unnaturally open in the minds of the sceptical to a certain doubt. For what one has not seen oneself is always received, if not with disbelief, at least with something bordering on incredulity; for which reason drawings are always looked at somewhat askance, especially if the markings depicted appear to be of an unexpected sort. Only when everybody can see the markings for himself are the drawings credited, and then so far as the detection of the markings goes the thing is ancient history. No new thing ever *is* but always *has been* seen. For the sight is never recognised generally until its first recognition is a thing of the past.

As prefatory to what I am about to give, I may mention four points about the markings which are of importance.

1. The markings seen here differ in kind from previous ones. They are not shadings more or less definite, but perfectly distinct markings. I have seen them when their contours had the look of a steel engraving.

2. They are *invariably* visible. Nothing but a very unsteady air can obliterate them.

3. They have been seen by everyone at the observatory who has made any systematic observations of the planets, Mr. Drew, Miss Leonard, and the writer, as well as by others and the drawings of all the observers agree as well as, if not better than, do their drawings of *Mars*. Up to February 6 the number of drawings was 227, showing a very remarkable accordance.

4. This observatory was founded for the express purpose of getting the best atmospheric conditions, which is by far the most important factor in planetary observations; and what I state of the markings is not surmise, but certainty.

Now although the markings were so distinct as to preclude any possibility of illusion, it is not to be expected that they can

seem so to those who have not observed them. It is therefore advisable to offer evidence which excludes illusion on its face. This is the case with the piece I am now to present.

As a globe turns in consequence of a revolution, orbital or axial, it presents a constantly changing face. On this face any markings must therefore be seen in continually changed positions. If the supposed markings be illusory, the observer of such an illusion must continually be determining unconsciously its position afresh. For such a determination to be performed unconsciously requires—

1. That the observer should estimate unconsciously not a direct quantity but a trigonometric function of the same—namely, the sine of a varying angle, the angular position of the point in question from the centre of the disc.

2. That he should do the like for the sine of a second angle, the angular position of the terminator from the same point.

3. That he should unconsciously combine the two determinations.

It is, I think, evident that such a determination and consequent location would be beyond the automatic possibilities of the most mechanically constituted brain. And this to say nothing of the fact that all the estimates are to be made from the centre of the disc only visible in part; an estimate practically impossible, either unconsciously or consciously.

Lastly, even if the unconscious cerebration should succeed it would speedily be betrayed; for, last but not least, any error it might make—and it would be certain to make some error—would be cumulative. It would increase with the time, for the action, being automatic, would lie beyond the pale of correction. It would gain or lose like a clock when kept under unchanging conditions.

Illusion, therefore, would be quite incapable of producing any nice accordance in the successively observed positions of a point upon a revolving globe. Now it is a very remarkable accordance of the sort which constitutes the fresh evidence of the isochronism of the orbital and axial periods. On measuring the position of *Bilit* on all my drawings made from the time of its first recognition to the close of my observations at Flagstaff, previous to moving to Mexico and tabulating the values, a most interesting result appeared. The measurements were made as follows: First, I measured on the original drawings the relative position of *Bilit* with regard to the limb and the terminator. Then I calculated the position of the terminator theoretically, and then corrected for limit of visibility from my measures of the planet's equatorial and polar diameters. This rendered its position independent of eye estimate. From the two resulting angles I deduced the longitude of *Bilit* on the disc. Now if the axial rotation coincided with the orbital revolution the resulting longitude for *Bilit* should be constant. That it was so, and to a surprising degree of accuracy, the subjoined table will show:—

Venus. Bilit.

Date.				Longitude, Central Meridian.	Cor. Libration.	Longitude of Bilit from Centre of Disc.	Longitude, Bilit.	Means.	
	h m	h m		°	°	°	°	°	°
Oct. 1	4 0	– 4 5		31·4	(−·7)	+6·4	37·8	38	37
	4 16	– 4 21		31·4	...	+4·3	35·7	36	
3	2 27	– 2 37		32·1	...	+4·9	37·0	37	35
	2 45	– 2 51		32·1	...	+0·2	32·3	32	
8	2 0	– 2 2		34·0	(−·6)	+2·0	36·0	36	36
	2 19	– 2 21		34·0	...	+2·5	36·5	36	
	4 42			34·0	...	+2·2	36·2	36	
9	1 59	– 2 28		34·4	...	−2·1	32·3	32	34
	2 48	– 2 56		34·4	...	+1·0	35·4	35	
	4 50	– 4 57		34·4	...	−0·6	33·8	34	
	5 3	– 5 8		34·4	...	+0·0	34·4	34	
13	2 55	– 3 4		35·9	(−·5)	+0·9	36·8	37	37
14	1 59	– 2 12		36·2	...	−0·3	35·9	36	36
	3 13	– 3 18		36·2	...	−1·1	35·1	35	
	3 50			36·2	...	+0·3	36·5	37	
15	0 5	– 0 14		36·5	...	+0·5	37·0	37	36
	1 0			36·5	...	−3·2	33·3	33	
	2 10	– 2 21		36·6	...	+1·2	37·8	38	
	3 48	– 3 54		36·6	...	−0·7	35·9	36	
	4 57			36·6	...	+1·0	37·6	38	
16	0 15	– 0 20		36·9	...	−4·9	32·0	32	34
	5 0	– 5 5		37·0	...	−0·8	36·2	36	
17	3 30			37·3	(−·4)	−3·3	34·0	34	34
19	3 25	– 3 34		38·0	...	+1·2	39·2	39	39
	5 5			38·0	...	+0·7	38·7	39	
20	1 0			38·3	...	+1·3	39·6	40	40
23	23 36	–23 45		39·4	...	−2·8	36·6	37	37
25	3 45			40·3	(−·3)	−3·2	37·1	37	37
	4 2	– 4 11		40·3	...	−2·4	37·9	38	
28	3 45	– 4 0		41·4	...	−4·6	36·8	37	37
	5 0			41·4	...	−4·0	37·4	37	
29	2 59	– 3 17		41·7	...	−5·2	36·5	36	36
	4 50	– 5 0		41·7	...	−6·0	35·7	36	
31	3 12	– 3 32		42·5	(−·2)	−6·7	35·8	36	37
	5 3			42·5	...	−4·0	38·5	39	

Date.					Longitude, Central Meridian.	Cor. Libration.	Longitude of Bilit from Centre of Disc.	Longitude, Bilit.	Means.	
	h	m	h	m	°	°	°	°	°	°
Nov. 2	2	58			43·3	...	−5·4	37·9	38	38
3	4	2–	4	10	43·7	...	−4·1	39·6	40	40
4	3	10–	3	16	44·0	...	−6·2	37·8	38	
	3	26–	3	37	44·0	(−·1)	−6·0	38·0	38	38
	4	58			44·0	...	−5·3	38·7	39	
5	3	32–	3	38	44·4	...	−7·3	37·1	37	37
7	4	40–	4	49	45·1	...	−6·8	38·3	38	38
9	0	30			45·8	...	−9·5	36·3	36	
	0	48–	0	54	45·8	...	−8·9	36·9	37	37
	1	58			45·8	...	−7·5	38·3	38	

Whence m, the arithmetical mean, = 36° ; r, the probable error of a single observation, = 1°·3 ; r_m the probable error of the arithmetical mean = 0°·2.

The first column gives the date ; the second the longitude of central meridian, the centre of the mean illuminated disc being taken as the zero meridian, and the longitude then corrected for libration ; the third, in brackets, the amount of such libration ; the fourth, the observed longitude of *Bilit* from the centre of the disc ; the fifth, the resulting longitude for *Bilit* from the zero meridian ; the sixth, the means.

Now as regards the longitude of *Bilit* on the surface of the planet the determination speaks for itself ; but as regards its disclosure of the isochronism of the axial and orbital rotations the evidence it gives is even more conclusive than at first appears. For while it would appear that the longitude of the centre of the disc shifted its position during the observations through 14°·4 (45°·8 − 31°·4), this shift was only the shift of phase (less the libration), the shift as regards the Earth. The shift as regards the Sun, or change in heliocentric longitude of the planet, was in the interval not 14°·4 but 62° ; and it is the latter taken in connection with the probable error of the longitude of *Bilit* that determines the degree of coincidence between the axial and orbital revolutions. As the probable error of the longitude of *Bilit* was 0°·2, the probable inaccuracy in the coincidence of the axial and orbital revolutions was therefore less than one three-hundredth of the whole. In other words, this is substantially absolute agreement ; for the resulting determination of the longitude of *Bilit* is as close as that of the best observed longitudes on *Mars*.

I may add that observations of *Bilit* up to February 6, the last made, are in accordance with it,

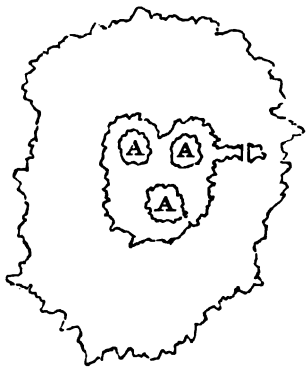
Lowell Observatory, Mexico :
1897 *February* 11.

The Nuclei of a Sun-spot. By T. K. Mellor.

On 1897 February 7 our sky here, which had been persistently overclouded for a number of days, became clear again, and on turning my telescope upon the Sun I saw a large spot with two or three smaller ones around it. It had already passed the centre, and was approaching the western limb, from which it was distant about a quarter of the Sun's diameter.

The spot, although large, was very much of the normal type, the umbra being surrounded by a symmetrical penumbra, the breadth of which was approximately that of the diameter of the umbra; but in addition to its size there were two features about it which attracted my attention, and made me determine to give it a very careful examination. I also made an outline sketch, a copy of which is appended.

It will be seen that at one place a long arm of the umbra projects into the penumbra, and the end of this arm was cut off and separated from the rest by a bright arc or bridge, which was as brilliant as a facula, and was very conspicuous against the darker background of the penumbra.



But what interested me more was the fact that the umbra itself was not of uniform darkness, as upon one side I saw a large patch, which was sensibly lighter in shade than the remainder, and soon afterwards I recognised something of the same kind upon the other side, although this was of smaller extent. In order to observe this better I removed the diagonal prism and dark glass which I was using and replaced them by a Dawes solar eyepiece. With a weak dark glass and a small diaphragm I was able to distinguish quite clearly that in the umbra there were three dark nuclei, marked A in the sketch, which were intensely black. Although the air was exceptionally steady this observation was difficult on account of the tremor caused by the heat and the constant lengthening and shortening of the focus;

but during the moments of best definition it appeared to me that these three nuclei were approximately circular, although I could not trace any distinct borders to them. They were all surrounded by the lighter background, and at no point did they touch the inner edge of the penumbra, but were always separated from it by an appreciable margin.

At first I supposed that what I saw was simply an effect of irradiation, but I satisfied myself that the phenomena were real.

The telescope is an equatorial refractor, by T. Cooke & Sons, of York, of 6 inches aperture, and the powers employed were from 60 to 200.

The contrast in colour between the black nuclei and the remainder of the umbra was very slight, but still it was distinctly perceptible, and by careful looking could be traced wherever it extended. These nuclei have been seen by former observers, and may possibly exist in every spot if we could but see them; but how they are caused or whether they are phenomena of growth or of decay must be left to the investigations of future observers.

Discordances of Index Errors of the Madras Mural Circle in the years 1834–1842 *inclusive.* By A. M. W. Downing, M.A., D.Sc., F.R.S.

In the course of the re-reduction of Taylor's Madras Observations, on which I am engaged, it became necessary to decide whether it was possible to make the declinations independent determinations, or whether it was necessary to make them differential with regard to an adopted standard catalogue, as Taylor had done. The materials for the former course are supplied by the observations of the "Reflecting Collimator," or of the nadir, as we should call it, which were commenced on 1834 August 11, and were continued (with some interruptions) from that date down to the end of the series of observations in 1842.

As the observations which were combined to form the Madras General Star Catalogue (which are those with which we are here concerned) extend from 1831 to 1842, it became necessary to ascertain whether the index errors deduced from the nadir bore any fixed or other determinable relation to those deduced from comparing the corrected circle-readings with the declinations of the Standard Catalogue. It would thus be possible to determine whether index errors corresponding to the nadir could be carried back to the commencement of the series of observations, and carried through the gaps in the nadir observations.

The adopted north latitude of the Madras Observatory, which has been applied to the nadir observations to obtain the index errors is 13° 4′ 8″·1. The substantial accuracy of this value

appears probable from a re-discussion of the direct and reflection observations of stars given on pp. 94, 95 of vol. i. of the Madras Observations. The corrected value of the latitude thus obtained is 13° 4′ 8″·04.

The standard declinations with which the corrected circle-readings are compared, to deduce the index errors from star observations, are those of Auwers' Mean System (*Ast. Nach.* 1536), and are found by applying the corrections given on page 12 of *Publication der Astronomischen Gesellschaft*, xiv. to the declinations of the Fundamental Catalogue published in the same volume. The stars used for index-error purposes are those of the Fundamental Catalogue situated to the south of dec. +55°.

The following table gives the mean correction to the index error from the nadir deduced from the index error from stars observed on the same day for each year of the series :—

Year.	No. of Comparisons.	Mean Correction.
1834	70	−1″·56 (from Aug. 11)
1835	277	−0·67
1836	253	−1·28
1837	225	−1·31
1838	199	−0·46
1839	115	−1·42
1840	107	−0·56
1841	70	−0·53 (to Sept. 25)
1842	127	−0·87 (from May 17)

The mean correction for the entire series is −0″·96, and the total number of comparisons is 1443.

The apparent correction to the adopted latitude is therefore +0″·96.

The next table shows the result of separating the observations in the four quarters of each year in order to see whether there is any marked change in the correction depending on the season of the year.

	1834.	1835.	1836.	1837.	1838.	1839.	1840.	1841.	1842.
	″	″	″	″	″	″	″	″	″
I.	...	−1·32	−1·31	−1·68	−0·89	−1·74	−0·12	−0·74	...
II.	...	−0·82	−1·86	−1·07	+0·05	−1·69	−1·04	−0·84	−2·13
III.	−1·07	+0·21	−1·06	−1·08	−0·02	−1·41	−0·54	−0·04	−0·55
IV.	−1·82	−0·65	−0·80	−1·24	−1·02	−1·00	−0·55	...	−0·58

The mean correction, the discordance of each mean result from the mean of all, and the R.A. at 10 hours M.T. (representing roughly the average time of star observations) for each group are shown in the next table.

	Mean Correction.	Discordance from Mean.	R.A. at 10 hrs.		Mean Correction.	Discordance from Mean.	R.A. at 10 hrs.
	s	s	h		s	s	h
I.	−1·11	−0·14	7	III.	−0·62	+0·35	19
II.	−1·18	−0·21	13	IV.	−0·96	+0·01	1

These annual discordances are of similar amount, though of quite dissimilar phase, to those found by Auwers from a comparison of Taylor's Catalogue (the declinations of which depend fundamentally on those of Pond's Catalogue of 1830) with the Fundamental Catalogue of the *Astronomische Gesellschaft*. The following table is deduced from his results (*Ast. Nach.* 3195):—

R.A.	Correction to Taylor.	R.A.	Correction to Taylor.
h	s	h	s
7	+0·04	19	+0·02
13	+0·23	1	−0·32

In view of the discordances here exhibited, both of a constant and periodic nature, it appears preferable to form the adopted index errors from a comparison of the corrected circle readings with the declinations of the Standard Catalogue rather than to attempt the formation of independent declinations which would involve so many elements of uncertainty. The former is consequently the course that has been adopted.

"Nautical Almanac" Office:
1897 *March* 8.

Cloud Statistics for Stations in India near the Path of the Moon's Shadow on 1898 *January* 21–22. By A. M. W. Downing, M.A., D.Sc., F.R.S.

Thanks to the kindness of Mr. J. Eliot, F.R.S., Meteorological Reporter to the Government of India, the cloud observations which are embodied in this paper were made at various points near the track of the total eclipse of next January, so as to be a guide to intending observers in the choice of stations.

My request for these observations for the latter part of 1894 January did not reach Mr. Eliot sufficiently early to enable him to make as complete returns for that year as he has done for the corresponding periods of 1895, 1896, and 1897. With the very complete organisation at his command, Mr. Eliot has been able (an opportunity of which he has not been slow to avail himself) to render a signal service to the science of astronomy.

The observations communicated to me consist of the hourly observation of the amount of cloud at each hour of the interval specified at the head of each yearly column in the following

tables. As it did not appear that any hourly variation in the amount of cloud could be detected in the observations, the mean of each hourly amount for the day has been taken to represent the daily amount referring in the mean to the approximate time of totality, or 1^h local mean time.

The columns in the tables under each year give, therefore, the mean daily amount of cloud at the station as thus determined for each day of the period over which the observations extend. The scale adopted is 0—10, where 0 represents a perfectly clear sky, and 10 a perfectly clouded one.

The mean daily amount of cloud for each station is also given.

These mean daily amounts of cloud are represented graphically in the diagram at the end of the paper, where the stations are arranged in order of longitude. The diagram shows clearly the increase in cloudiness as we proceed further towards the east. In fact, from the west coast to 76° E. the average amount of cloud is represented by 1 on the adopted scale; whilst from 78° E. to 85° E. the average amount of cloud is represented by 2. At Darjeeling (the most easterly place of observation) the increase is so great (7·7) that it cannot conveniently be represented on the diagram.

Those who wish for a clear sky would do well, therefore, to locate themselves to the west of the range of hills running from Ahmednagar to Hyderabad. The remarkable general absence of cloud during the latter part of 1896 January is noteworthy.

The detailed observations received from India have been handed over to the custody of the Joint Permanent Eclipse Committee, so as to be available for reference.

Ratnagiri.

East long. 73° 19′; North lat. 17° 0′.

	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.		1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.
Jan. 12	...	1	0	Jan. 22	0	1	0
13	...	0	0	23	0	0	0
14	...	0	2	24	1	0	0
15	...	0	0	25	2	0	0
16	...	5	0	26	...	1	4
17	0	0	0	27	...	3	6
18	0	2	5	28	...	2	8
19	0	1	0	29	...	0	8
20	0	0	1	30	...	0	0
21	0	0	0	31	...	0	0

Mean daily amount of cloud 1·1.

Vengurla.

East long. 73° 39′; North lat. 15° 52′.

	1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.
Jan. 22	1	Jan. 25	1	Jan. 28	6	Jan. 31	0
23	1	26	0	29	1		
24	3	27	0	30	0		

Mean daily amount of cloud 1·3.

Marmagao.

East long. 73° 48′; North lat. 15° 24′.

	1895. 10^h-4^h.		1895. 10^h-4^h.		1895. 10^h-4^h.		1895. 10^h-4^h.
Jan. 22	0	Jan. 24	0	Jan. 26	1	Jan. 28	1
23	0	25	0	27	1		

Mean daily amount of cloud 0·4

Satara.

East long. 74° 1′; North lat. 17° 41′.

	1896. 10^h-4^h.	1897. 11^h-3^h.		1896. 10^h-4^h.	1897. 11^h-3^h.
Jan. 12	0	1	Jan. 22	0	2
13	0	0	23	0	2
14	0	3	24	0	2
15	1	3	25	0	2
16	2	0	26	0	2
17	0	0	27	0	7
18	0	2	28	0	8
19	1	1	29	0	8
20	0	4	30	0	0
21	0	2	31	0	0

Mean daily amount of cloud 1·3.

Belgaum.

East long. 74° 31′; North lat. 15° 50′.

	1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.
Jan. 21	0	Jan. 24	6	Jan. 27	0	Jan. 30	0
22	0	25	0	28	6	31	0
23	1	26	0	29	0		

Mean daily amount of cloud 1·2.

Sholapur.

East long. 75° 54′; North lat. 17° 39′.

	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.		1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h
Jan. 12	...	0	0	Jan. 22	0	0	3
13	...	0	0	23	0	0	0
14	...	0	0	24	...	1	0
15	...	0	1	25	...	0	0
16	...	5	0	26	...	0	4
17	0	0	0	27	...	0	3
18	0	0	0	28	...	0	8
19	0	0	2	29	...	0	8
20	1	0	1	30	...	0	0
21	0	0	2	31	...	0	0

Mean daily amount of cloud 0·8.

Wardha.

East long. 78° 36′; North lat. 20° 44′.

	1897. 11^h-3^h.		1897. 11^h-3^h.		1897. 11^h-3^h.		1897. 11^h-3^h.
Jan. 12	2	Jan. 17	0	Jan. 22	1	Jan. 27	3
13	0	18	2	23	3	28	8
14	0	19	5	24	1	29	7
15	1	20	4	25	4	30	0
6	0	21	3	26	8	31	0

Mean daily amount of cloud 2·6.

Nagpur.

East long. 79° 5′; North lat. 21° 8′.

	1894. 11^h-1^h.	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 10^h-4^h.		1894. 11^h-1^h.	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 10^h-4^h.
Jan. 12	...	...	0	3	Jan. 22	1	6	0	7
13	...	...	0	1	23	4	0	1	5
14	...	...	0	0	24	0	1	1	3
15	...	...	0	3	25	1	3	0	3
16	...	...	1	0	26	0	5	0	7
17	...	...	0	0	27	0	...	1	7
18	...	...	0	4	28	2	...	1	7
19	...	3	1	7	29	0	...	2	7
20	...	3	0	5	30	3	...	0	0
21	...	5	0	6	31	0	...	0	0

Mean daily amount of cloud 2 0.

Jubbulpur.

East long. 79° 58′; North lat. 23° 9′.

	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.		1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.
Jan. 12	...	0	1	Jan. 22	4	0	5
13	...	0	0	23	...	0	8
14	...	0	0	24	...	0	7
15	...	0	4	25	...	0	1
16	7	1	0	26	...	0	3
17	1	0	0	27	...	0	9
18	0	0	3	28	...	1	2
19	2	0	9	29	...	0	5
20	2	0	4	30	...	1	0
21	5	2	9	31	...	0	2

Mean daily amount of cloud 2·1.

Benares.

East long. 83° 0′; North lat. 25° 20′.

	1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.		1895. 10^h-4^h.	1896. 10^h-4^h.	1897. 11^h-3^h.
Jan. 12	...	0	1	Jan. 22	6	0	5
13	...	0	0	23	...	0	10
14	...	0	4	24	...	0	6
15	...	0	5	25	...	0	3
16	5	1	0	26	...	0	4
17	3	0	0	27	...	0	7
18	0	0	4	28	...	1	0
19	3	0	10	29	...	0	0
20	2	1	3	30	...	0	0
21	0	7	8	31	...	0	0

Mean daily amount of cloud 2·1.

Gorakpur.

East long. 83° 23′; North lat. 26° 44′.

	1895. 10^h-4^h.		1895. 10^h-4^h.		1895. 10^h-4^h.		1895. 10^h-4^h.
Jan. 17	4	Jan. 19	3	Jan. 21	2	Jan. 23	8
18	0	20	1	22	8		

Mean daily amount of cloud 3·7

Patna.

East long. 85° 11′; North lat. 25° 33′.

	1894. 11^h-1^h.	1896. 10^h-4^h.	1897. 11^h-3^h.		1894. 11^h-1^h.	1896. 10^h-4^h.	1897. 11^h-3^h.
Jan. 12	...	0	0	Jan. 22	8	0	9
13	...	0	0	23	7	0	5
14	...	0	0	24	2	1	5
15	...	0	1	25	1	0	5
16	...	0	0	26	0	0	5
17	...	0	0	27	0	0	9
18	...	0	1	28	0	9	0
19	...	3	10	29	0	3	0
20	...	0	2	30	0	0	0
21	...	3	8	31	0	0	0

Mean daily amount of cloud 2·0.

Hazaribagh.

East long. 85° 20′; North lat. 23° 59′.

	1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.
Jan. 22	9	Jan. 25	0	Jan. 28	0	Jan. 31	0
23	10	26	0	29	0		
24	0	27	0	30	0		

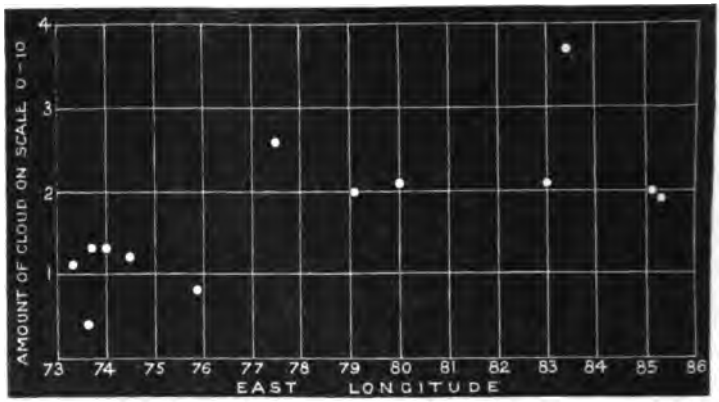
Mean daily amount of cloud 1·9.

Darjeeling.

East long. 88° 18′; North lat. 27° 3′.

	1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.		1894. 11^h-1^h.
Jan. 22	5	Jan. 25	3	Jan. 28	9	Jan. 31	10
23	6	26	10	29	10		
24	4	27	10	30	10		

Mean daily amount of cloud 7·7.



Mean amount of cloud in day-time during the latter part of January at stations in India near the path of the moon's shadow on 1898 Jan. 21–22.

Observations taken at Vadsö during the total Eclipse of the Sun, 1896 *August* 9. By Passengers of the S.S. *Neptun* (Norwegian).

(*Drawn up and Communicated by T. C. Porter, Eton College.*)

A. *Direction and Force of Wind.* By E. E. Wilde.

The position taken up was near the edge of the southern cliffs of the island opposite Vadsö, and was about 200 yards E.N.E. of the British Astronomical Association's station; the arrangements, four long pieces of wood laid on the ground pointing N., S., E., and W. respectively, set by the compass *uncorrected for magnetic deviation*. For a flag a very thin piece of old cambric was used, fastened to a crooked stick.

During most of the eclipse there was not sufficient air to lift it, though it flapped gently. At 4.20 there was sufficient air to keep it fully extended, and at 4.25 it was still stronger, calling for the additional note between the 10^m observations arranged to be noted. By 4.50 it had decreased, and continued doing so till totality. The wind observations were taken more than 100 yards distance from Mr. Weir, who was observing temperature, stationed on the rather lower ground to the north-west.

B. *Atmospheric Temperature.* By Thomas Weir (Manchester).

The thermometer used was a mercurial with a long glass spiral in place of the ordinary bulb, specially made by Casartelli & Son (Manchester), very sensitive to change, and ranging from 20° to 120° Fahrenheit. The scale was read with a magnifying glass.

C. *Colour of Sky, Land, and Sea.*

Four observers * noted these during the progress of the eclipse on sheets of paper having the outlines of the scenery filled in before hand, and on each sheet the landscape colour was written on the corresponding part of the already drawn landscape. Two observers took the view east of the Sun, two that to the west, and each entered the time of beginning and ending each sheet as it was used, the position of the Sun being marked by a large dot on each sheet.

	h m s		h m s
First contact	4 1 6	End of totality	4 58 44
Beginning of totality	4 56 59	Last contact	5 56 42

D. *The Shadow Bands or Striæ.*

Two pairs of observers armed with sticks and sheets watched carefully for these ; but though to almost all the darkness seemed to come on in distinct pulsations, which may be due to the varying rate of the dilatation of the pupil, no shadow bands were observed.

E.

Six other observers, one with a 4-inch refractor, another with two cameras (one of which was provided with a large Nicol), and the remaining four with prepared charts, had intended to map the corona in quadrants, to note its structure, and examine it in two rectangular directions for polarisation, but clouds prevented any work of this kind being done.

Two accounts of the eclipse are appended. The words written at the time by T. C. Porter are copied from his notes almost verbatim ; the other by E. A. Mason, written out just afterwards from a rough account written during the eclipse.

* M. Roberts, J. M. Hughes, G. Hutchings, and John Cordeaux. A brief summary of the observations will be found in the table at the end, arranged chronologically. The time throughout is "Continental."

General Account. By T. C. Porter.

The first contact ($4^h\ 1^m$) was not observed, the sky being overcast with grey stratus cloud, thin overhead, yellowish brown about 45° W. of the Sun, not so deeply coloured the same distance to the E. The point opposite the Sun is yellowish brown. There are a few clear spaces of very light blue sky ($4^h\ 10^m$).

A slight, very small rain falls for a few minutes; patches of sunshine are visible on the hills to the E., which are of a French-blue-mixed-with-white colour. The sky in the W. is gradually clearing, details on the hills to the E. growing clearer ($4^h\ 24^m$).

The light on the horizon to the N.W. grows brighter, but in front, under the Sun (N.E.), it grows rather darker. The clouds near the Sun get darker and more brown, whilst long bluish rifts are drifting slowly from the N.W. towards the N.E. ($4^h\ 31^m$).

At $4^h\ 35^m$ the clouds are distinctly growing to the W. of the Sun. Over it is forming a herring-bone arrangement of cumulo stratus. A slight but very distinct breeze from the N.W. sprung up at $4^h\ 37^m$, the lines of cloud under the Sun are becoming more and more defined and heavier-looking, of a slaty-blue near the horizon.

At $4^h\ 40^m$ seven birds flew past towards the south, all calling.

At $4^h\ 45^m$ four birds flew by towards the north. It has grown sensibly colder; wind very faint from the same quarter. Yellowish ochre gleams on the N.N.E. horizon, then two ravens flying north and croaking loudly went by: they separated, one flying round by N. and W.

The blue sky is getting more like indigo, the clouds the same colour, only darker.

Totality seemed to come on in waves of darkness (*vide* foot-note in table) just *after* the signal given by the British Astronomical Association, the spaces in the sky where the veil of cloud was very thin turning a sickly yellow ochre colour. There is a dead silence, a brilliant red orange sky on the N. and N.W. horizon, *very* dark indigo and muddy French blue clouds, and

Chronological Summary of Observations on the Total Solar Eclipse of 1896 *August* 9.

Time G. Europ. h m s	Temp. F. °	Wind Direction	Wind Force	Colour of Land West of Sun	Colour of Land East of Sun
3 30 0	45				
3 45 0	44½	N. slightly E.	*Very* light		
4 0 0	44½	,,	,,		
4 1 6		First contact.			
4 10 0		N. slightly W.	*Very* light	Dist. purple; mid. dist. green from vegetation (A)	
4 15 0	45				
4 20 0		N.N.W.	Very light but increasing		
4 25 0	45	N.N.W.	Still increasing		

just under where the Sun lies hidden, and about 2° above the horizon, a few torn, fleecy clouds, bright silver grey, illuminated intensely on the under surfaces (light reflected from the Sun shining on the sea beyond the path of the Moon's umbra). It was quite easy to read the seconds-hand of my watch, and just possible to read the largest letters of the ordinary Wilson S.S. luggage label on my telescope-box cover, standing seven feet away. It was easy to see one's pencil writing, and would have been easy to draw without any artificial light. The sky in one place where it could be seen was a purple colour. The sea between the island and Vadsö was easily seen, but it was impossible to make out objects clearly where they had the turf, &c., of the island we were on for background. The Moon's shadow was seen passing off to the north-east at the close of totality.

General Account. By E. A. Mason.

I was on the island close to Vadsö, away from the rest of my party, undisturbed, and gave my whole senses to observation. The colour of the sky was neutral tint (at the beginning of the eclipse), the sea very grey, and the land a sombre hue. The light began to fade gradually at first, but when totality began a sudden rush of darkness came. A gentleman who was standing some little way off, and whose figure had stood out against the horizon, became enveloped in it and was lost to view. The darkness cleared off as suddenly as it came on. . . . I had near me all the time a reindeer, four sheep, and six ponies. Till the end of totality they were all lying down, then the sheep and ponies got up at once and began to move about, as if they, like myself, felt relieved from the feeling of intense darkness. The reindeer, which was standing grazing when the eclipse began, lay down as it grew darker, as if night had come, and, unlike the other animals, did not move again. The seabirds kept up a perpetual twittering the whole time. The stars were not visible during the eclipse at all. The metal surface of my knife had drops on it after totality, and, though I did not feel it myself, I believe some rain fell in a misty kind of way.

as seen from Vadsö, Varanger Fjord, by some of the passengers of S.S. *Neptun*.

Sea	Sky			Remarks
	West of Sun		East of Sun	
Slate and silver greys (A)	Greys			About 4.15 a slight shower of small rain fell (E)

Time O. Europ. h m s	Temp. F. °	Wind Direction	Force	West of Sun	Colour of Land East of Sun
4 30 0		N.N.W.	Light		
4 35 0	45				Dist. indigo blue; foreground brown and green (C)
4 40 0	44½	N.N.W.	Light		
4 45 0	44				Dist. pale grey blue (B); mid dist. green and grey (B); foreground green (B)
4 48 0					
4 50 0	44	N.N.W.	Light and decreasing	Hills in purple shadow as on a clear night (D)	Dist. blackish blue (C); foreground grey brown (C)
4 51 0					
4 55 0	43½	N.W.	Decreasing		Dist. dull grey blue (B)
4 56 0		N.W.	Still decreasing		Mid dist. dull green (B); foreground dull green (B)
4 56 59	Totality (by calculation)		Stiller, if possible	Dist. hills dark purple (A); foreground yellow green (A)	Dist. hills brown black (C); mid dist. green black (C); foreground lighter green black (C)
4 57 30	Mid totality.				
4 58 44	End of totality (by calculation)				
4 59 0					Dist. hills indigo (C); mid dist. green with grey lights (C); foreground green with golden lights (C)
5 0 0	43½	N.W.	Very light		
5 5 0	44				
5 10 0		N.W.	Very light		
5 12 0					
5 15 0	44½				
5 20 0		N.W.	Very light		
5 30 0	45				
5 35 0		N.W.	Decreased		
5 45 0	45½				
5 56 42	Last contact.				
6 0 0	46	N.	*Very* light, scarcely perceptible		

Observers indicated by the capital letters in brackets:—(A) M. Roberts, observing W. G. Hutchings, observing E. of Sun from the island; (D) J. Cordeaux, observing W. of Sun

N.B.—The events on each horizontal line in this table happened at the time marked in throughout the eclipse.

Sea	Sky: West of Sun	Sky: East of Sun	Remarks
Leaden grey (C)		Grey, blue grey, and high lights pale gold (C)	Clouds began to assume the look of parallelism in W.N.W. to N.N.W. (E)
Dull grey, part greenish yellow (B)		Clouds grey; lights sickly yellow	Much darker. Two ravens crossed the harbour croaking. Oyster catchers on wing calling "peep, peep."
	Clouds dark grey and faint purple (A); "touched along edges with pink" (D)	Heavy looking snow clouds, a strip of blue sky, high lights pale yellow (B)	Some rain (misty) fell
Greyish green (B)			
Dark grey (C); sickly green (B); dark grey under clouds, bright under the horizon gleam (A)	Dark blue grey clouds, bright orange yellow rift near horizon (A)	Black grey clouds, high lights golden, bluish grey near horizon (C)	4.57.—The Moon's shadow visible at a great distance, the darkness coming on in rapid and very distinct pulsations or throbs, about 6 a second (D)
	Some torn feathery clouds bright grey and intensely illuminated on under surfaces about 2° above N.N.E. horizon: they were lower than the other clouds (E)	Near the Sun the horizon was yellowish flame-coloured, fading into pale yellow further east (B)	During totality "nothing invisible far or near" (D) No shadow bands observed either before or after totality
Silver grey (C)	Grey (A)	Dark blue grey (C)	4.59.—Shadow seen retiring like a thunderstorm gloom (E) Rapid return of light (D)
			Linear appearance of cloud quite gone (E)

of Sun from the island; (B) J. M. Hughes, observing E. of Sun from the island; (C) from Vadsö Harbour; (E) T. C. Porter, observing from the island.
the first column on the left; thus it is easy to see the progress of the different phenomena

Observations of Comets and Planets made with the 15-inch Dunecht Refractor and Wire Micrometer at the Royal Observatory, Blackford Hill, Edinburgh. By Dr. J. Halm.

(*Communicated by the Astronomer Royal for Scotland.*)

1896	M.T. Edinburgh. h m s	$\delta\alpha$ (♂ − ✱) m s	$\delta\delta$ (♂ − ✱) ′ ″	No. of Comp.	*Comet* 1896 IV. α App. h m s	Log $p\Delta$.	δ App. ° ′ ″	Log $p\Delta$.	Reduction to App. Pl. α	δ	No. of Comp. Star.
Sept. 14	10 17 5	−1 14·72	− 2 0·7	21, 7	14 44 33·90	9·729	+53 54 18·8	0·741	+0·86	− 2″·6	1
					Comet 1897 (*Perrine*, 1896 *Nov.* 2).						
Nov. 4	12 6 1	−1 29·96	− 1 53·9	9, 3	20 18 30·95	9·549	+23 41 23·9	0·850	+2·30	+19.3	2
5	9 22 32	−1 44·36	+ 3 59·4	9, 3	20 17 0·91	9·502	+22 58 14·4	0·764	+2·30	+18·9	3
8	6 10 44	−0 39·51	− 5 16·7	21, 7	20 12 35·39	9·039	+20 42 18·5	0·713	+2·29	+17·6	4
8	6 31 32	−0 16·90	+ 3 42·2	18, 6	20 12 33·81	9·143	+20 41 39·7	0·718	+2·29	+17·5	5
13	7 46 54	−0 40·91	+ 6 52·4	24, 8	20 6 9·29	9·414	+16 57 42·3	0·780	+2·29	+15·4	6
16	8 2 10	+0 37·45	− 4 25·1	24, 8	20 3 1·91	9·455	+14 53 50·0	0·802	+2·29	+14·2	7
16	9 3 9	−1 18·18	− 9 25·4	12, 4	20 2 59·77	9·512	+14 52 17·6	0·823	+2·29	+14·4	8
18	5 36 8	+0 38·93	− 4 14·4	30, 10	20 1 17·80	9·106	+13 39 19·0	0·778	+2·29	+13·5	9
29	5 38 35	+0 35·90	+ 3 17·1	24, 8	19 54 11·32	9·285	+ 7 17 32·7	0·827	+2·34	+ 9·8	10
29	5 59 32	−1 0·49	+ 1 59·0	15, 5	19 54 10	9·336	+ 7 17	0·830	+2·35	+10·0	11
30	5 36 44	−1 12·49	+ 7 0·9	18, 6	19 53 44·24	9·290	+ 6 46 40·0	0·831	+2·36	+ 9·7	12
Dec. 11	6 29 21	−0 19·61	− 5 14·2	24, 8	19 50 20·92	9·461	+ 1 40 49·7	0·858	+2·43	+ 6·9	13
13	5 23 12	+1 17·92	− 3 5·2	24, 8	19 49 59·68	9·378	+ 0 52 31·8	0·860	+2·45	+ 6·4	14
23	5 19 14	+0 43·51	+ 3 26·9	15, 5	19 48 51·10	9·436	− 2 55 29·9	0·871	+2·56	+ 4·6	15
23	5 33 11	−1 16·92	+ 4 19·6	15, 5	19 48 51·20	9·453	− 2 55 37·2	0·870	+2·57	+ 4·9	16

Comet 1896 (*Perrine, Dec.* 8).

1896.	M.T. Edinburgh. h m s	Δα. (♂ − ✱) m s	Δδ. (♂ − ✱) ′ ″	No. of Comp.	α App. h m s	Log $p\Delta$.	δ App. ° ′ ″	Log $p\Delta$.	Reduction to App. Pl. s	″	No. of Comp. Star.
Dec. 11	5 45 4	−2 42·65	+ 3 35·5	18, 6	1 9 32·54	9·223*n*	+ 5 24 14·4	0·836	+4·19	+27·2	17
11	8 41 43	−1 51·45	+ 0 32·7	15, 5	1 10 23·75	8·902	+ 5 21 11·6	0·834	+4·20	+27·2	17
22	7 59 11	+1 11·35	+ 4 14·1	15, 5	2 23 53·69	8·396*n*	+ 1 34 18·5	0·854	+4·50	+23·5	18
23	6 35 14	+1 56·53	+ 7 10·1	18, 6	2 29 38·42	9·159*n*	+ 1 19 53·0	0·857	+4·50	+23·1	19
				◯ 1894 *A.Y.*							
Sept. 15	10 34 10	+1 45·79	+ 5 11·7	15, 5	20 26 46·28	9·183	− 6 45 46·2	0·890	+3·83	+10·9	20
				(106 *Dione.*							
Sept. 17	11 14 35	+1 2·89	−10 56·8	15, 5	23 53 33·67	8·854*n*	− 8 7 45·2	0·898	+4·17	+26·4	21
29	9 57 24	+1 6·39	− 8 18·4	15, 5	23 44 35·76	9·007*n*	− 8 51 20·2	0·900	+4·24	+25·7	22
Oct. 5	10 2 36	+1 2·98	− 4 56·1	15, 5	23 40 28·20	8·713*n*	− 9 6 56·7	0·902	+4·25	+25·3	23
				92 *Undina.*							
Sept. 17	12 4 3	+0 43·00	+ 3 6·6	15, 5	0 59 24·22	8·977*n*	− 9 37 38·7	0·903	+4·06	+28·9	24
Oct. 12	10 6 22	−1 7·14	− 5 47·2	18, 6	0 41 32·86	8·992*n*	−11 33 41·9	0·908	+4·31	+27·4	25
21	9 53 11	+1 1·92	− 8 45·5	18, 6	0 35 35·33	8·758*n*	−11 51 21·4	0·911	+4·33	+26·3	26
22	11 42 25	−0 39·82	+ 3 22·7	12, 4	0 34 56·34	9·036	−11 52 30·8	0·909	+4·33	+26·2	27
24	10 28 50	−1 47·68	+ 1 58·8	12, 4	0 33 48·48	8·182	−11 53 54·8	0·912	+4·33	+26·1	27

(104) *Klymene.*

1896.	M.T. Edinburgh.	Δα.	Δδ.	No. of Comp.	α App.	Log pΔ.	δ App.	Log pΔ.	Reduction to App. Pl.		No. of Comp. Star.
	h m s	m s	″		h m s		° ′ ″		s	″	
Sept. 29	11 8 58	−1 23·36	−10 28·2	15, 5	0 19 57·92	8·691*n*	− 0 47 33·1	0·867	+4·16	+27·7	28
Oct. 12	9 21 21	+0 46·19	+ 0 30·7	18, 6	0 10 24·28	9·053*n*	− 1 35 47·2	0·870	+4·19	+27·3	29

(225) *Henrietta.*

Sept. 29	11 58 15	−1 50·42	− 6 5·4	15, 5	23 57 55·15	8·738	+ 9 43 8·1	0·803	+4·07	+27·3	30
Oct. 8	8 8 56	−1 4·61	+ 1 7·2	18, 6	23 53 0·45	9·314*n*	+ 7 57 52·8	0·825	+4·09	+27·7	31

(80) *Sappho.*

Oct. 8	10 18 18	−0 16·36	+ 5 38·0	18, 6	1 52 54·50	9·304*n*	+16 37 20·6	0·766	+4·31	+27·2	32
21	10 52 14	+0 41·62	− 7 6·5	18, 6	1 43 3·01	8·846*n*	+13 58 12·2	0·772	+4·41	+28·6	33
22	11 17 41	−2 18·31	− 5 14·0	15, 5	1 42 15·95	8·402*n*	+13 45 2·0	0·772	+4·42	+28·6	34
24	10 57 30	−1 38·32	+ 1 2·3	15, 5	1 40 46	8·618*n*	+13 20 .	0·775	+4·42	+28·7	35

(209) *Dido.*

Nov. 2	11 1 27	+1 45·70	− 3 43·2	15, 5	2 40 49·36	8·878*n*	+22 52 25·8	0·684	+4·78	+26·6	36
3	11 58 46	+0 51·82	− 6 15·5	15, 5	2 39 55·50	8·336	+22 49 53·5	0·682	+4·80	+26·6	36
4	9 9 35	+0 6·33	− 8 27·3	6 6	2 39 10·02	9·342*n*	+22 47 41·8	0·717	+4·81	+26·7	36

(195) *Eurykleia.*

1896.	M.T. Edinburgh.	Δα. (○ − ✱)	Δδ.	No of Comp.	α App	Log pΔ.	δ App.	Log pΔ	Reduction to App Pl.		No of Comp. Star.
	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Nov. 2	11 51 19	−0 58·15	+ 8 0·2	15, 5	2 59 23·78	8·429*n*	+24 0 32·3	0·667	+4·87	+25·0	37
3	12 18 48	−1 56·26	+ 6 20·9	12, 4	2 58 25·68	8·386	+23 58 53·1	0·668	+4·88	+25·1	37
4	9 35 14	−2 47·20	+ 4 49·7	3, 1	2 57 34·75	9·328*n*	+23 57 22·0	0·702	+4·89	+25·2	37
13	9 6 54	−3 39·80	− 5 33·3	12, 4	2 48 58·76	9·282*n*	+23 37 52·3	0·699	+4·96	+26·4	38

(82) *Alkmene.*

Nov. 13	9 53 47	−2 49·61	+ 8 8·2	12, 4	2 33 49·21	8·992*n*	+16 39 29·3	0·751	+4·76	+27·1	39

(233) *Cyrene.*

Dec. 8	12 23 6	+0 12·52	−10 7·8	12, 6	5 53 52·17	8·474*n*	+31 45 58·1	0·555	+6·07	+ 6·7	40

(8) *Flora.*

Nov. 29	10 23 38	+2 54·70	− 4 56·9	12, 4	4 43 40·65	9·171*n*	+14 15 49·3	0·776	+5·15	+16·6	41
Dec. 8	11 17 7	−1 59·83	− 1 34·2	15, 5	4 33 38·52	7·695*n*	+14 35 56·8	0·764	+5·26	+16·8	42
11	9 18 21	+2 5·74	− 1 18·9	12, 4	4 30 36·02	9·191*n*	+14 44 23·2	0·772	+5·27	+17·5	43
15	11 48 38	+1 16·79	+ 4 36·3	15, 5	4 26 34·94	8·965	+14 57 46·0	0·764	+5·30	+17·7	44

Mean Places of Comparison Stars.

No.	R.A. 1896·0.	Decl. 1896·0.	Authority.
	h m s	° ′ ″	
1	14 45 47·76	+53 56 22·1	A.G.Z., Cambr.
2	20 19 58·61	+23 42 58·5	A.G.Z., Berlin B.
3	20 18 42·97	+22 53 56·1	,,
4	20 13 12·61	+20 47 17·6	,,
5	20 12 48·42	+20 37 40·0	,,
6	20 6 47·91	+16 50 34·5	A.G.Z., Berlin A.
7	20 2 22·17	+14 58 0·9	½ (Bessel + Lamont).
8	20 4 15·66	+15 1 28·6	A.G.Z., Berlin A.
9	20 0 36·58	+13 43 19·9	Lamont.
10	19 53 33·08	+ 7 14 5·8	½ (Bessel + Lamont).
11	19 55 9	+ 7 15	B.D. + 7° 4330.
12	19 54 54·37	+ 6 39 29·4	Lamont.
13	19 50 38·10	+ 1 45 57·0	A.G.Z., Albany.
14	19 48 39·31	+ 0 55 30·6	Bessel – Weisse.
15	19 48 5·03	− 2 59 1·4	,,
16	19 50 5·55	− 3 0 1·7	München.
17	1 12 11·00	+ 5 20 11·7	½ (Schj. + A.G.Z., Alb.)
18	2 22 37·84	+ 1 29 40·9	A.G.Z., Albany.
19	2 27 37·39	+ 1 12 19·8	,,
20	20 24 56·66	− 6 51 8·8	Lamont.
21	23 52 26·61	− 7 57 14·8	Bessel – Weisse.
22	23 43 25·13	− 8 43 27·5	,,
23	23 39 20·97	− 9 2 25·9	,,
24	0 58 37·16	− 9 41 14·2	Schjell.
25	0 42 35·69	−11 28 22·1	,,
26	0 34 29·08	−11 43 2 2	⅓ (Armagh + Bruxelles).
27	0 35 31·83	−11 56 19·7	Bessel – Weisse.
28	0 21 17·12	− 0 37 32·6	Göttingen,.
29	0 9 33·90	− 1 36 45·2	,,
30	23 59 41·50	+ 9 48 46·2	½ (Bessel + Rümk.).
31	23 54 0·97	+ 7 56 17·9	Bonn Beob.
32	1 53 6·55	+16 31 15·4	A.G.Z., Berlin A.
33	1 42 16·98	+14 4 50·1	Bessel – Weisse.
34	1 44 29·84	+13 49 47·4	Lalande.
35	1 42 20	+13 18	B.D. + 13° 276.
36	2 38 58·88	+22 55 42·4	A.G.Z., Berlin B.
37	3 0 17·06	+23 52 7·1	,,

No.	R.A. 1896·0. h m s	Decl 1896·0. ° ′ ″	Authority.
38	2 52 33·60	+23 42 59·2	A.G.Z., Berlin B.
39	2 36 34·06	+16 30 54·0	A.G.Z., Berlin A.
40	5 53 33·58	+31 55 59·2	½ (Bessel + Bruxelles).
41	4 40 40·80	+14 20 29·6	Bessel – Weisse.
42	4 35 33·09	+14 37 14·2	,,
43	4 28 25·01	+14 45 24·6	,,
44	4 25 12·85	+14 52 52·0	½ (Arm. + Bruxelles).

Notes.

Sept. 14.—Comet exceedingly faint.

Nov. 4.—(195). Observation interrupted by clouds.

Nov. 4.—Comet exceedingly faint, scarcely visible.

Nov. 13.—During the observation of the comet a strong wind shook the instrument. The comet resembles a faint nebula with a distinct nucleus of about 13th magnitude.

Nov. 16.—Comet very faint; fog and moonlight.

Nov. 18.—Comet well seen, though faint.

Dec. 13.—Comet very faint. Hazy sky and moonlight.

Dec. 22.—Comet faint.

Dec. 23.—*Perrine*, Nov. 2, is a very distinct round nebulosity.

Dec. 23.—*Perrine*, Dec. 8, has an oval form and nucleus of 11th magnitude.

Transit Circle Observations of Comet Swift (1896 *April* 13) *at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations, excepting May 2, were made with illuminated wires. A power of 80 was used on each night :—

Greenwich Mean Solar Time of Transit (sub polo).	Observer.	Apparent R.A. of Comet.	Apparent N.P.D. of Comet (Uncorrected for Parallax).	Parallax q.	Log $(q \times \Delta)$.
1896. h m s		h m s	° ′ ″	″	
Apr. 30 12 27 57·6	W.	3 0 40·03	37 55 18·5	13·8	0·9327
May 1 12 18 53·5	W.	2 55 30·99	36 11 3·0	13·4	0·9293
2 12 9 31·6	R.	2 50 3·95	34 33 57·1	13·1	0·9257
4 11 50 3·7	W.	2 38 26·09	31 38 46·9	12·4	0·9183
11 10 36 20·2	W.	1 52 6·40	24 27 50·6	10·4	0·8946
13 10 14 20·7	R.	1 37 56·36	23 5 6·9	9·9	0·8891
14 10 3 16·7	W.	1 30 47·16	22 28 27·9	9·7	0·8865

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85, and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, No. 3,349.

Observers' Remarks.

April 30.—The comet appeared as a large diffused mass about 0′·8 in diameter, difficult to observe; there was no definite condensation. Only one bisection secured in N.P.D. Sky rather thick.

May 1.—Round patch of light; a condensation showed now and then, but difficult to bisect properly.

May 2.—Observed in a nearly dark field; observation not satisfactory; very difficult.

May 4.—Only a very approximate observation; sky very thick.

May 11.—Good observation.

May 13.—Very difficult, faint; sky hazy.

May 14.—Observation considered very fair for so faint an object.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson.

Radcliffe Observatory, Oxford:
1897 *March* 11.

Ephemerides for Physical Observations of Mercury.

By A. Marth.

Though the assumption of the coincidence of the plane of *Mercury's* equator with that of the orbit is arbitrary, it is at present the only one available, if the wishes of observers for ephemerides are to be complied with. I now give such ephemerides covering the times of Mr. Percival Lowell's observations made in the autumn of 1896, and also the part of the next synodical revolution, during which observations may be procurable. As it is simpler to employ in the computations the planet's geocentric ecliptical longitudes and latitudes, not published in the *Nautical Almanac*, I have used the places of the *Connaissance des Temps*, so that the data of the ephemeris are true ones for Paris noon, and apparent ones for Greenwich noon $+\tau$.

P denotes the position-angle of the assumed axis of rotation, reckoned, as usually, from the declination circle.

L+180 and B, the longitude and latitude of the Earth referred to the planet's orbit, the longitude being reckoned from the perihelion.

ω_0 the hermographical longitude of the central meridian on the supposition that the period of rotation coincides with the planet's return to perihelion, or the angle "Mean Anomaly − L." If n is considered the daily rate of rotation "Const. $+n(t-t_0)$ − L" must be substituted.

d, the apparent diameter, 6″·68 being the assumed value at distance 1.

q and Q, the amount and position-angle of the greatest defect of illumination, q being expressed in parts of the diameter.
v the angle between Sun and Earth, as seen from *Mercury*.

1896.		t	P	L	B	ω_0	d	q	Q	v
		m	°	°	°	°	"		°	°
Sept.	1	+0·1	28·53	108·10	+5·75	57·87	5·89	·270	115·5	62·59
	2	0·0	·61	109·45	5·78	60·62	5·96	·281	115·8	64·00
	3	−0·1	·68	110·77	5·80	63·39	6·03	·292	116·0	65·43
	4	0·2	·73	112·07	5·82	66·18	6·10	·304	116·2	66·88
	5	−0·4	28·77	113·34	+5·85	69·00	6·18	·316	116·4	68·36
	6	0·5	·80	114·58	5·87	71·85	6·26	·328	116·6	69·87
	7	0·6	·82	115·80	5·89	74·73	6·34	·341	116·8	71·41
	8	0·7	·83	116·98	5·92	77·64	6·43	·354	117·0	72·99
	9	−0·8	28·82	118·13	+5·94	80·59	6·52	·367	117·2	74·61
	10	1·0	·81	119·24	5·97	83·57	6·61	·381	117·4	76·29
	11	1·1	·79	120·32	5·99	86·58	6·71	·396	117·5	78·02
	12	1·2	·76	121·36	6·02	89·63	6·82	·412	117·7	79·81
	13	−1·3	28·73	122·35	+6·04	92·73	6·93	·428	117·8	81·67
	14	1·5	·69	123·31	6·07	95·87	7·04	·445	118·0	83·61
	15	1·7	·65	124·21	6·10	99·06	7·16	·462	118·2	85·62
	16	1·8	·61	125·06	6·12	102·30	7·28	·480	118·4	87·72
	17	−1·9	28·56	125·86	+6·15	105·60	7·41	·499	118·6	89·92
	18	2·0	·51	126·60	6·18	108·95	7·55	·519	118·8	92·22
	19	2·1	·46	127·27	6·20	112·37	7·69	·540	119·0	94·64
	20	2·3	·42	127·87	6·23	115·86	7·84	·563	119·2	97·19
	21	−2·4	28·38	128·39	+6·25	119·43	7·99	·586	119·5	99·87
	22	2·5	·34	128·84	6·28	123·08	8·15	·610	119·8	102·69
	23	2·7	·31	129·20	6·30	126·81	8·31	·635	120·1	105·67
	24	2·8	·29	129·46	6·32	130·64	8·48	·661	120·5	108·82
	25	2·9	·28	129·62	6·33	134·57	8·65	·689	120·9	112·16
	26	3·0	·29	129·67	6·34	138·61	8·82	·717	121·4	115·69
	27	−3·2	28·30	129·61	+6·35	142·77	9·00	·746	121·9	119·43
Oct.	15	−3·1	28·72	114·37	+5·75	231·67	8·91	·858	294·8	135·71
	16	2·9	·71	114·00	5·78	236·13	8·66	·815	295·8	129·15
	17	2·7	·70	113·83	5·80	240·39	8·40	·770	296·6	122·71
	18	2·5	·69	113·84	5·82	244·47	8·15	·722	297·2	116·41
	19	−2·3	28·69	114·04	+5·85	248·37	7·90	·673	297·6	110·27
	20	2·1	·69	114·41	5·87	252·09	7·65	·624	298·0	104·32
	21	1·9	·69	114·94	5·89	255·65	7·42	·575	298·3	98·58
	22	1·6	·68	115·62	5·92	259·06	7·20	·527	298·6	93·05
	23	−1·4	28·67	116·45	+5·94	262·33	6·99	·480	298·8	87·74

		t m	P °	L °	B °	ω_0 °	d ″	q	Q °	v °
1896. Oct.	24	1·2	·65	117·40	5·97	265·48	6·79	·436	298·9	82·66
	25	0 9	·62	118·45	5·99	268·52	6·61	·394	299·0	77·81
	26	0·7	·58	119·60	6·02	271·46	6·44	·355	299·1	73·19
	27	−0·5	28·52	120·83	+6·05	274·32	6·28	·319	299·1	68·81
	28	0·3	·45	122·13	6 07	277·11	6·13	·286	299·1	64·65
	29	−0·1	·36	123·49	6·10	279·84	6·00	·255	299·0	60·70
	30	+0·1	·25	124·90	6·12	282·52	5·88	·227	298·9	56·97
	31	0·3	28·12	126·36	6·15	285·16	5·76	·202	298·8	53·44
Nov.	1	0·5	27·98	127·85	6·18	287·76	5·66	·179	298·6	50·10
	2	+0·6	27·81	129·37	+6·20	290·33	5·56	·159	298·4	46·93
	3	0·8	27 62	130·91	6·23	292·88	5·47	·140	298·2	43·94
	4	1·0	27·41	132·47	6·25	295·41	5·38	·123	297·9	41·11
	5	1·1	27·17	134·05	6·28	297·93	5·31	·108	297·6	38·43
	6	+1·3	26·92	135·64	+6·30	300·43	5·24	·095	297·2	35·89
	7	1·4	26·64	137·24	6·32	302·93	5·17	·083	296·8	33·47
	8	1·5	26·35	138·84	6·33	305·42	5·11	·072	296·4	31·18
	9	1·6	26·03	140·45	6·34	307·90	5·06	·063	295·9	29·00
	10	+1·7	25·69	142·06	+6·35	310·38	5·01	·054	295·4	26·93
1897. Apr.	9	+1·2	332·39	312·23	−2·52	34·06	5·26	·054	67·4	26·78
	10	1·1	332 67	314·30	2·46	36·08	5·32	·071	66 8	30·94
	11	1·0	332·99	316·35	2·41	38·12	5·39	·091	66·4	35·17
	12	0·8	333·34	318·37	2·36	40·19	5·47	·114	66·2	39·46
	13	+0·7	333·71	320·37	−2·31	42·29	5·56	·139	66·1	43·81
	14	0·5	334·10	322·33	2·25	44·43	5·65	·167	66·1	48·17
	15	0·3	334·52	324·24	2·20	46·61	5·75	·196	66·2	52·54
	16	+0·1	334·95	326·10	2·14	48·83	5·86	·227	66·3	56·89
	17	−0·1	335·40	327·92	−2·09	51·11	5·98	·259	66·5	61·19
	18	0·3	335·86	329·68	2·03	53·45	6·11	·292	66·8	65·45
	19	0·5	336·32	331·37	1·97	55·85	6·24	·326	67·1	69·65
	20	0·7	336·79	333·00	1·91	58·31	6·38	·360	67·4	73·77
	21	−0·9	337·27	334·56	−1·84	60·84	6·53	·394	67·7	77·81
	22	1·1	337·74	336·05	1·77	63·44	6·69	·428	68·0	81·77
	23	1·3	338·20	337·46	1·69	66·12	6·86	·462	68·3	85·65
	24	1·5	338·65	338·80	1·61	68·88	7·04	·495	68·7	89·45
	25	−1·7	339·09	340·06	−1·53	71·71	7·22	·528	69·0	93·17
	26	1·9	339·51	341·24	1·44	74·62	7·41	·559	69·4	96·81
	27	2·1	339·92	342·34	1·35	77·61	7·61	·590	69·7	100·38
	28	2·2	340·31	343·36	1·25	80·69	7 82	·620	70·0	103·89

1897.		t m	P °	L °	B °	ω_0 °	d ″	q	Q °	v °
Apr.	29	−2·4	340·67	344·29	−1·14	83·85	8·03	·649	70·3	107·34
	30	2·6	341·01	345·14	1·02	87 09	8·25	·677	70·6	110·75
May	1	2·8	341·32	345·90	0·90	90·42	8·47	·704	70·9	114·12
	2	3·0	341·60	346·57	0·77	93·84	8·70	·730	71·2	117·44
	3	−3·1	341·85	347·16	−0·63	97·35	8·94	·755	71·5	120·73
	4	3·3	342·07	347·66	0·48	100·94	9·17	·779	71·8	124·01
	5	3·4	342·25	348·07	0·33	104 62	9·41	·803	72·0	127·28
	6	3·6	342·40	348·39	−0·17	108·39	9·65	·825	72·3	130·55
	7	3·7	342·52	348·62	+0·01	112 26	9·89	·846	72·5	133·81
	8	3·9	342·61	348·76	0·19	116·24	10·13	·866	72·8	137·08
	9	−4·0	342·65	348·82	+0·38	120·24	10·36	·885	73·1	140·37
	29	−4·5	339·86	340·21	+4·44	210·70	11·56	·944	241·3	152·52
	30	4·5	339·77	339·92	4·57	215·07	11·40	·931	242·0	149·49
	31	4·4	339·71	339·71	4·68	219·38	11·23	·917	242·6	146·51
June	1	4·3	339·67	339·57	4·79	223·62	11·05	·902	243·2	143·58
	2	−4·2	339·66	339·50	+4·88	227·78	10 85	·887	243·7	140·71
	3	4·1	339·67	339·51	4·96	231·86	10·65	·871	244·2	137 89
	4	4·0	339·70	339·59	5·03	235·87	10·45	·854	244·6	135 12
	5	3·9	339·76	339·75	5·09	239·80	10·24	·837	245·1	132·39
	6	−3·8	339·85	339·98	+5·15	243·66	10·03	·819	245·6	129·71
	7	3·7	339·96	340·29	5·19	247·44	9·82	·801	246·0	127·07
	8	3·6	340·10	340·68	5·23	251·15	9·61	·783	246·5	124·46
	9	3·4	340·27	341·14	5·26	254·78	9·40	·764	247 0	121·88
	10	−3·3	340·46	341·68	+5·28	258·34	9·19	·745	247·5	119·32
	11	3·2	340·68	342·29	5·29	261·82	8·98	·725	248·0	116·77
	12	3·0	340·93	342·97	5·30	265·23	8·77	·705	248·5	114·23
	13	2·9	341·21	343·72	5·30	268·58	8·57	·685	249·1	111·70
	14	−2·7	341·51	344·53	+5·30	271·86	8·38	·664	249·7	109·16
	15	2·6	341·85	345·41	5·30	275·07	8·19	·643	250·3	106·61
	16	2·4	342·21	346·36	5·29	278·21	8·00	·621	250·9	104·04
	17	2·2	342·61	347·37	5·28	281·29	7·81	·599	251·5	101·45
	18	−2·1	343·03	348·45	+5·26	284·31	7·63	·577	252·2	98·83
	19	1·9	343·49	349·58	5·24	287·27	7·46	·554	252·9	96·16
	20	1·7	343·98	350·78	5·22	290·16	7·29	·530	253·7	93·45
	21	1·6	344·51	352·04	5·19	292·99	7·13	·506	254·5	90·68
	22	−1·4	345·07	353·36	+5·17	295·76	6·97	·481	255·3	87·85
	23	1·2	345·66	354·74	5·14	298·48	6·82	·456	256·1	84·94
	24	1·0	346·29	356·17	5·11	301·14	6·67	·430	257·0	81·96
	25	0·8	346·96	357·66	5·09	303·74	6·53	·404	258·0	78·89

1897.		t m	P °	L °	B °	$\omega_\odot$ °	d °	q	Q °	v °
June	26	−0·7	347·67	359·21	+5·06	306·28	6·40	·377	259·0	75·73
	27	0·5	348·41	0·82	5·03	308·77	6·27	·350	260·0	72·48
	28	0·3	349·19	2·48	5·00	311·20	6·14	·322	261·1	69·12
	29	−0·2	350·01	4·19	4·97	313·58	6·03	·294	262·3	65·66
	30	0·0	350·86	5·96	4·95	315·90	5·92	·266	263·5	62·09
July	1	+0·2	351·75	7·78	+4·92	318·18	5·81	·238	264·8	58·42
	2	0·4	352·68	9·64	4·90	320·41	5·71	·211	266·2	54·65
	3	0·5	353·65	11·55	4·88	322·59	5·62	·184	267·7	50·78
	4	0·7	354·65	13·51	4·86	324·72	5·54	·158	269·2	46·82
	5	0·8	355·67	15·51	4·84	326·82	5·46	·133	270·9	42·79
	6	+1·0	356·72	17·54	+4·83	328·88	5·38	·110	272·7	38·69

I am quite willing to comply with the wishes of several observers and prepare similar ephemerides for *Venus*; but as the sketches are scattered, and at present only partly accessible, I require information about the dates, and also references to the published sketches, so that they may be consulted when I get the opportunity.

Colonel Cooper's Observatory,
Markree, Collooney, Ireland.

Attempt to photograph the Leonids in the Open Sky.

By Isaac Roberts, D.Sc., F.R.S.

The first opportunity for attempting to photograph the *Leonid* meteor swarm occurred on the morning of Sunday last, February 28, between the hours of $0^h\ 30^m$ and $3^h\ 30^m$. The sky was fairly clear and the conditions generally favourable for the trial.

Two very sensitive plates were simultaneously exposed with their centres pointed to the part of the sky given in the ephemeris, and the exposure continued during $2^h\ 45^m$. The negatives are of good quality, and the one exposed in the 20-inch reflector shows stars to the faintness of about 17th magnitude, whilst the plate exposed in the camera with 5-inch portrait lens shows stars to 15th magnitude.

The photo-field of the reflector plate is 2°, and that of the camera plate 17°, in diameter.

On careful examination of the two plates I can detect no indication whatever of either the meteor stream or the comet that is expected to accompany it.

The conclusion at which I have arrived by these experiments is that the meteor stream, if it should at present be within a radius of $8\frac{1}{2}°$ with the computed position as a centre, does not emit or reflect light which would be equal to that of a star of the 15th magnitude, nor, if it is within a radius of 1° of the computed point as a centre, emit or reflect light that would be equal to that of a star of the 17th magnitude.

We may therefore conclude that the stream cannot be photographed during the present interval, but it is very desirable that another ephemeris should be computed in time for making a trial again next winter. The ephemeris should include the months of November, December, January, February, and March.

Errata in Mr. Tebbutt's Observations of Minor Planets.

Vol. lvi. page 352, line 14 from top *for* May 1 5·3 *read* May 18 5·3.
Vol. lvii. „ 26 „ 11 „ under Mean Time of *Nautical Almanac* *read* $0^h\ 0^m$.
Vol. lvii. page 26, line 17 from top under Mean Time of *Nautical Almanac* *for* $1^h\ 24^m$ *read* $1^h\ 24^m\ 0^s$.
Vol. lvii. page 30, line 7 from bottom *for* $10^h\ 3^m\ 20^s$ *read* $10^h\ 3^m\ 20{\cdot}5^s$.

„	„	76	„	9	„	top	„	+1 1·21	„	+1 2·21.
„	„	77	„	5	„	„	„	14 26 9·099	„	14 26 9·09.
„	„	77	„	4	„	bottom	„	+6 17·9	„	−6 17·9.
„	„	79	„	7	„	top	„	+2 36·54	„	−2 36·54.
„	„	79	„	9	„	bottom	„	9·519n	„	9·510n.
„	„	81	„	5	„	top	„	Radcliffe 1893	*read*	Radcliffe 1890.
„	„	81	„	3	„	bottom	„	112 59 20·4	„	112 59 20·0

Errata in Radcliffe Observations of Comet Perrine-Lamp, vol. lvii. page 181.

	Parallax in N.P.D.			Log. ($\rho \times \Delta$).		
Feb. 23 (*a*)	*for* 14″·1	*read*	15″·9.	*For* 0·7377	*read*	0·7897.
(*b*)	„ 14·2	„	15·8.	„ 0·7416	„	0·7862.
Mar. 3 (*d*)	„ 6·0	„	10·0.	„ 0·5077	„	0·7267.
16 (*g*)	„ 4·6	„	5·0.	„ 0·6509	„	0·6955.
Apr. 9 (*j*)	„ 2·5	„	3·2.	„ 0·6617	„	0·7634.
10 (*k*)	. . . .			„ 0·7140	„	0·7189.

Errata in Professor Schur's Paper on the Diameter, &c., of Mars.

Vol. lvii. page 151, third number in last column, *for* 6·11 *read* 6·21.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. APRIL 9, 1897. No. 6

Sir R. S. BALL, LL.D., F.R.S., President, in the Chair.

John Franklin-Adams, Wimbledon ;
Rev. Sherrard Beaumont Burnaby, M.A., The Vicarage, Hampstead, N.W. ;
John Sisson Slater, M.A., LL.D., Seafield House, Lytham, and 1 Garden Court, Temple, E.C. ; and
Rev. John Spence, 27 Walpole Street, Chelsea, S.W.,

were balloted for and duly elected Fellows of the Society.

The following candidate was proposed for election as a Fellow of the Society, the name of the proposer from personal knowledge being appended :—

Professor Henry C. Lord, Director of the Emerson McMillin Observatory, Ohio State University, Columbus, Ohio, U.S.A. (proposed by George E. Hale).

Seventy-one presents were announced as having been received since the last meeting, including, amongst others—

H. Jacoby, Reduction of Stellar Photographs, &c, presented by Columbia College Observatory ; Meudon, Observatoire d'Astronomie Physique, Annales, tome i., presented by the Observatory ; S. Newcomb, Action of the Planets on the Moon, and Secular Variations of the Orbits of the Four Inner Planets,

presented by the office of the *American Ephemeris*; W. J. S. Lockyer, Resultate aus Beobachtungen des veränderlichen Sternes η *Aquilæ*; W. Prinz, Esquisses Sélénologiques, presented by the authors; two MS. volumes containing original entries of Capt. Foster's pendulum observations, 1828–31, presented by the Hydrographer.

On some Original Unpublished Observations of the Comet of 1652.

By E. B. Knobel.

In a copy of the second edition of Bayer's *Uranometria* (Ulm, 1639), with which is bound the *Cœlum Stellatum Christianum* of Julius Schiller (Augsburg, 1627), which I have recently acquired, there are recorded several observations of the comet of 1652, and as they appear to be for the most part the original observations of the former owner of the work, they are perhaps worth saving from the obscurity in which they have been concealed since that period.

The comet of 1652 was very carefully observed by Hevelius, who devotes the whole of the first book of his "Cometographia" to an exhaustive discussion of his observations, and it was from these materials that the elements of the comet's orbit were subsequently computed by Halley, and published in his well-known "Synopsis," which appeared in the *Philosophical Transactions* for 1705.* Besides his own very important series, Hevelius mentions some observations made by Wendelinus at Tournai, Malvaticæus at Bologna, Christianus at Giessen in Hesse, and by an Englishman at Aleppo, but it is clear that neither of these can be the author of the observations I have discovered. It is probable, however, that the author is indicated in an inscription on the title-page of Bayer, in the same handwriting as that of the observations. This inscription gives an epitome of the title-page of the "Coelum Stellatum," and concludes with the sentence: "A. 1649 pro isto Coelo Stellato petebat D(ominus) Henri(cus) Milius ? nuper."

This author had evidently the open maps before him, on which he each night marked down the position of the comet by alignment with the stars, and he wrote on the maps particulars of such alignment with notes and remarks, as well as some observations made elsewhere by others.

Hevelius observed the comet from 1652 December 20 to 1653 January 8. Our unknown author gives the positions of the comet from December 19 to January 3, and there is a note which

* In his "Constantes de l'Astronomie" (*Annales de l'Observatoire de Bruxelles*) Houzeau gives Halley's longitude of perihelion erroneously as 38° 10′ 40″; it should be 28° 10′ 40″.

indicates that the comet was observed as late as 1653, January 20. These dates are new style.*

From several references in the notes to observations at Cologne, and also to some made at a monastery in Westphalia, I infer that the author may probably have lived at Cologne, where I found the work; indeed, as a matter of fact, the book belonged to the library of a Burgomaster at Cologne when I bought it.

The positions of the comet marked on the maps being those derived solely from alignment with the stars, they are of course of the same epoch as *Bayer's Uranometria*, which is that of *Tycho's Catalogue*, A.D 1601. I have taken out the longitudes and latitudes from the maps, and reduced the longitudes to 1653, and compared the results with those observations of Hevelius nearest in time, and as these latter were made, as is well known, at Danzig, I have corrected the times given by my unknown author (assumed as for Cologne) to the meridian of Danzig.

The following are the positions and notes exactly as given in the manuscript, on the maps :—

	Longitude.	Latitude.	Notes.
1652 Dec. 19	68° 40′	36° 20′ S.	19 Dec. inter pedes *Orionis*.
„ 20	66 30	30 20 S.	20 Dec. Bononiæ in Italia h. 3½ post ⊙ occasum.
„ 20	66 20	29 30 S.	20 Dec. contra genu occidentale *Orionis*.
„ 21	62 40	18 25 S.	21 Dec. 1652 h. 7½ post merid. Monasterij Westphaliæ efficiebat Triang. æquilaterũ cũ duabus scũt *Orionis* maxime distantibus secundum Henr. Moderton. (?) qui addit 3 fere gr. ad polũ ab æquatore
„ 21	...	...	21 Dec. contra scutum *Orionis* Colon. Studiosi.
„ 21	62 30	17 30 S.	Circa hunc locũ visus cometes 21 Dec. a Studiosis Colon. Vespere diei S Thomæ.
„ 22	60 10	9 30 S.	22 Dec. h.
„ 22	60 20	9 30 S.	22 Dec. 1652 Hora 8 sero.
„ 26	53 20	13 25 N.	26 Dec. 1652 Sero h. 9. Colon.
„ 26	53 15	13 20 N.	26 Dec. 1652 in Latit. 37 fere visus Cometa sero h. 9.
„ 27	52 35	15 10 N.	27 Dec. h. 5 mane prope occasũ et ideo cũ parallaxi quam Dec. 27 eodẽ vesperexit vesp̃tina obseruatis.
„ 27	...	...	Mane 27 Dec. hora 5 erat inter duas rectas duobus a Pleiadibus ad Lucidissimam in pectore Persei et ab ijsdem ad Lucidissimam capitis Medusæ ducta verò linea per utramque stellam pedis.

* There is a possibility of uncertainty about dates in Germany at this period, for though new style was introduced into that country so early as 1584, it was not generally adopted till 1699 November.

	Longitude.	Latitude	Notes.
1652 Dec. 27	52° 15′	16° 30′ N.	27 Dec. sero h. 10 exacte obseruaui crucē notatam in Lat. 40 f.
„ 27	52 0	16 30 N.	27 Dec. mihi 25 ab oculo Tauri.
„ 28	52 30	17 30 N.	28 Dec. 1652 Manc h. 5 Coloniæ apparebat Cometa.
„ 28	51 20	19 0 N.	28 Dec. sero h. 9 Lat. B. 42½.
„ 29	51 20	21 40 N.	29 Dec. Vesp. h. 8 deficiens Lat. B. 45.
„ 30	...	...	30 Dec. h. 2 post mediam noctē stetit in hac linea inter oculū Medusæū et lucidam in genu Persei ductâ sic ut attingeret pene oculum Medusæ, ex occidente imo mane eodem h. 6 iam subingressus eundem oculū ita obnubilabat eum, ut is esset obscurior quam stella p̄xima supra genu.
„ 30	50 25	23 30 N.	30 Dec. h. 6 sero Lat. B. 47 f.
1653 Jan. 3	48 20	28 35 N.	3 Jan. mane h. 4 Latit. 51½ fere.
„ 20	36 20?	43 35 N.?	Hoc triangulū æquilaterum 6½ gr. labi longiore efficiebat Monasterij Westphaliæ 20 die Januarij ad vesperā hora 8.

Positions reduced to 1653, *and the times corrected to the meridian of Danzig, compared with Hevelius* :—

	Auctor in Bayer.				*Hevelius.*		
Date.	Time.	Long.	Lat.		Time.	Long.	Lat.
	h m	° ′	° ′		h m	° ′	° ′
1652 Dec. 19	?	69 24	36 20 S.		...	...	...
„ 20	8 21 P.M.	67 14	30 20 S.		7 0 P.M.	68 24	30 49 S.
„ 20	?	67 4	29 30 S.		...	...	...
„ 21	8 2 P.M.	63 24	18 25 S.		...	...	...
„ 22	?	60 54	9 30 S.		...	...	...
„ 22	8 47 P.M.	61 4	9 30 S.		...	...	...
„ 26	9 47 P.M.	54 4	13 25 N.		9 0 P.M.	54 0	13 24 N.
„ 26	9 47 P.M.	53 59	13 20 N.				
„ 27	5 47 A.M.	53 19	15 10 N.		2 6 A.M.	54 17	13 53 N.*
„ 27	10 47 P.M.	52 59	16 30 N.		11 44 P.M.	53 23	17 5 N.
„ 27	?	52 44	16 30 N.		...	...	...
„ 28	5 47 A.M.	53 14	17 30 N.		0 13 A.M.	53 14	17 6 N.
„ 28	9 47 P.M.	52 4	19 0 N.		...	...	...
„ 29	8 47 P.M.	52 4	21 40 N.		5 0 A.M.	52 21	20 33 N.
„ 30	6 47 P.M.	51 9	23 30 N.		6 10 P.M.	51 28	23 23 N.
1653 Jan. 3	4 47 A.M.	49 4	28 35 N.		6 47 P.M.	50 10	29 2 N.
„ 20	8 47 P.M.	37 4	43 35 N.				

* Hevelius's Latitude is clearly in error and that in the MS. is more correct.

The comet was not observed by Hevelius on December 19, 21, and 22.

With respect to the above observations, that recorded as made at Bologna on December 20 was probably by Cornelius Malvaticæus mentioned by Hevelius. The comet is indicated as on a line with β *Eridani* and 27 *Orionis*. On December 21, at 8.2 p.m. Danzig time, the comet formed an equilateral triangle with π^3 and π^5 *Orionis*. On December 22 it is shown between μ and ρ *Tauri*, and nearly on a line with them. On December 27, probably at 10.47 p.m. Danzig time, the author gives the angular distance of the comet from α *Tauri* as 25°. Hevelius measured the same angle at $5^h\ 38^m$ Danzig time the same evening and made it 24° 16½′. On this date, at 10.47 p.m. Danzig time, the author shows the comet exactly on a line joining o and ρ *Persei*, and also on a line joining 39 *Arietis* and ϵ *Persei*, these lines being nearly at right angles, and thus form the cross referred to under this date.

On December 28, at 9.47 p.m. Danzig time, the comet is shown between ϵ *Persei* and δ *Trianguli* and exactly on the line joining them. On December 29, at 8.47 p.m. Danzig time, it is on the line joining ξ and β *Persei*, and also on the line joining δ and ω *Persei*. On December 30, at 2 hours "post mediam noctem," 2.47 a.m. Danzig time, the comet was on the line joining ϵ and β *Persei*; and on January 3 the comet made a right angle with α and β *Persei*, and was situated slightly south of a line joining α *Persei* and γ *Andromedæ*.

With respect to the observation dated January 20 at 8 p.m., "Hoc triangulum æquilaterum 6½ gr. labi longiore efficiebat Monasterii Westphaliæ 20 die Januarii ad vesperam hora 8," the point marked on the map is about 6½° from each of the two stars in the Sword of Perseus, marked v and g in Bayer, = Fl. 1 and Fl. 4, which are also about 6½° from each other. But there must necessarily be a doubt whether the comet was really observed in this position. From December 23 to January 7 the position of the comet had altered in longitude only 9°, whereas in latitude it had moved 35°. On this latter date it was about 2° south of τ *Persei*, where it was last seen by Hevelius. From January 4 to January 7 the apparent motion of the comet was slow, in a path passing between γ and τ *Persei*; and it is extremely difficult to understand how it could be in the position assigned on January 20. If it be true, it is an important observation; but there is a suspicion of a mistake, seeing that the assigned place on January 20 is very close to two stars θ and μ *Cassiopeiæ*, which are within 52′ of longitude and 18′ of latitude of each other, and in hazy weather might thus have led the observer to believe that he saw the comet. The Moon was not above the horizon at the time.

Hevelius observed the comet from December 20 to January 8, but in his Table of Comets he states that it lasted till 1653 January 10; and he further makes a statement respecting the distance of the comet "vero 12 Januarii." His remarks on its

motion, as translated by Sherburne (*Manilius*, p. 210), are :— "Its motion was constantly retrograde, from South to North, by the Hare, Foot of *Orion*, *Taurus*, to the *Pleiades*; and from thence as far as *Perseus*; not directly but obliquely from East South East to North North West, in a great circle inclined to the Ecliptick, and Æquator: At first by its diurnal motion compleating 11° 16′, at last 30′, it ran through in the time of its duration 65° 51′ passing beyond and beside the course of the Annual Orb."

Hevelius declares positively that the comet disappeared after January 10. His words are: "Quamobrem serio sum persuasus ultimo hâc die esse visum; et postmodum à nemine observatum esse: quemadmodum et mihi, die 11 Januarii, nusquam apparuit." There is a further marginal note: "Nullus, præter autorem, cometam ad 11 usque Januarii observavit."

The observations of December 21, 26, 27, 28, 29, 30, and January 3, which state that the "latitude" of the comet was 3°, 37°, 40°, 42½°, 45°, 47°, and 51½° respectively, must not be taken as the latitude from the ecliptic; but they are what Hevelius terms "Distantia ab intersectione Æquatoris"—that is to say, the angular distance of the comet from the equator in its apparent orbit considered as a great circle.*

On the Straightness of Spider Lines.

By H. H. Turner, M.A., B.Sc., Savilian Professor.

1. The gist of the following note is that the horizontal wire of the Greenwich Transit Circle is sensibly straight. I was led to examine this point from hearing that a curvature or "sag" of the horizontal wire had been detected elsewhere. If such a curvature existed it would specially affect the R—D observations, and might form a considerable part of this curious phenomenon.

2. The method adopted was to take from the section of observed zenith-distances in the volumes of Greenwich Observations for 1892 and 1893 all those cases in which a star had been observed in zenith-distance at the vertical wires 1, 2, 6, 7. The readings of the micrometer at wires 1 and 7 were subtracted

* In the copy of Bayer under consideration, the author of the observations has designated the group of stars 33, 35, 39, and 41 *Arietis* as "Nubes *Tauri* vel Halitus *Arietis*." These stars formed the constellation "Musca," or "Apes," of Jacobus Bartchius, the son-in law of Kepler, and I am unaware of any other designation for them than his. The explanation of "Nubes *Tauri*" is that the stars are situated on the confines of the cloud which conceals the body of the Bull, as shown in the old drawings of the constellations in Aratus and Hyginus, and in Bayer. "Halitus *Arietis*" is explained by the face of the Ram being turned in the direction of these stars, and thus the animal's breath would cover them.

from those at wires 2 and 6. If the path of the star across the field were a straight line, and there were any "sag" of the wire, the result (2+6)—(1+7) would be positive. The inclination of the wire to the horizontal would be eliminated.

3. The path of a star is, however, curved, and the correction for curvature is given in the Greenwich Observations as

$$+0^{r}\cdot00327 \times \cot \text{N.P.D.} \times (\text{wire}-4)^{2},$$

the unit 1^{r} being a revolution of the telescope micrometer, $=37''\cdot05$, so that $^{r}\cdot00327 = 0''\cdot121$ (it is convenient to keep our figures in revolutions of the micrometer). Thus the correction to the quantity tabulated (2+6)—(1+7) is

$$+\{(2^{2}+2^{2})-(3^{2}+3^{2})\} \times {}^{r}\cdot00327 \times \cot \text{N.P.D.}$$

or

$$-{}^{r}\cdot0327 \times \cot \text{N.P.D.},$$

which was accordingly applied to the results.

4. In the following table the results are given, arranged according to N.P.D. The approximate mean N.P.D. of the group is given in the *first* column, each group including all the stars within 10° of N.P.D. In the *second* column is given the curvature correction corresponding to this mean N.P.D., to give an idea of its magnitude. The observations were, however, each corrected separately, and not by use of this mean correction. In the *third* column is given the flexure factor sin Z.D. It seems probable that if there were any sag in the wire, it would be greater at large zenith-distances, according to some law like that of flexure.

N.P.D.	Correction for Curvature.	Factor for Flexure.	Readings at wires (2+6)—(1+7); corrected for curvature. 1892,.	No. Obs.	1892,.		1893.		Mean.	
°	r		r		r		r		r	
45	−0·033	0·10	−·015	8	−·016	6	−·002	7	−·011	21
55	−0·022	0·28	−·003	14	−·001	6	−·011	13	−·006	33
65	−0·015	0·44	−·002	37	−·002	10	+·001	18	−·001	65
75	−0·009	0·59	−·004	20	−·004	16	+·004	17	−·001	53
85	−0·003	0·72	+·016	9	+·005	12	+·001	11	+·007	32
95	+0·003	0·83	−·002	12	+·007	14	+·001	9	+·002	35
105	+0·009	0·91	+·001	10	+·011	8	+·006	22	+·006	40
115	+0·015	0·97	+·003	6	−·007	19	−·006	13	−·005	38
123	+0·022	1·00	+·048	2	−·004	4	−·018	9	−·005	15

In columns 4, 6, 8, are given the mean results of three series of groups, corresponding to the dates 1892 January 1–June 30, 1892 July 1–December 31, 1893 January 1–December 31: the number of stars in each group being shown in columns 5, 7, and 9. Columns 10 and 11 give the weighted means (according to number of observations) and weights for all the stars.

5. There appears to be no evidence of curvature in the wire. The simple mean of column 10 is $-^{r}\cdot0016$, and the weighted mean $-^{r}\cdot0008$; equivalent to $-0''\cdot06$ and $-0''\cdot03$ respectively; and indicating an *upward* curvature if anything. If we equate the results of column 10 to k sin Z.D., and solve by least squares, we get

$$k = -^{r}\cdot0003 = -''\cdot01.$$

6. The negative value for 45° is noteworthy, especially as the few available observations on the north side of the zenith also give negative results, as follows—

-45°	$-^{r}\cdot018$	-36°	$-^{r}\cdot051$	$+25^{\circ}$	$-^{r}\cdot082$	$+28^{\circ}$	$-^{r}\cdot009$
-42	$-\cdot042$	-35	$+\cdot007$	$+25$	$-\cdot032$	$+35$	$-\cdot011$

But there are not enough observations to settle anything definitely about this side of the zenith. There is one way in which such negative results for stars above the pole may be spurious, viz. if the observer inadvertently transposes the readings of the micrometer at wires 1 and 2, or at 6 and 7. Such errors would give negative results in the above investigation.

7. It occurred to me as possible that the law assumed for curvature of the star's path might not be sufficiently accurate near the pole; but a very little examination showed that it is accurate enough except for close polar stars, which are not usually observed far from the meridian at Greenwich. I take this opportunity of pointing out another case where the use of rectangular coordinates simplifies the problem very much.

8. The accurate formula for correcting for curvature is given by Chauvenet (vol. ii. p. 291) as

$$-\frac{\sin^2\frac{1}{2}(\tau-m)}{\sin 1''}\cdot\sin 2\delta' - \frac{2\sin^4\frac{1}{2}(\tau-m)}{\sin 1''}\sin 2\delta'\sin^2\delta', \text{ \&c.}$$

where τ is the east hour angle of the star, and c, m and n are the usual instrumental constants. It will be noted that c and n do not appear in this expression. If we use rectangular coordinates x and y along the horizontal and vertical wires respectively; then, since the path of the star is an ellipse (the projection of a small circle on a plane) its equation is

$$y = ax^2 + by^2.$$

To find a and b, perhaps the simplest plan is to take three rectangular axes S O, S P, and a perpendicular to both; where O is the centre of the celestial sphere, O P the polar axis, S the star, and S P a tangent to the sphere at S. The coordinates of O are (0, 0 1) if S P be taken as axis of y and S O of z; and the coordinates of P are (0, tan p, 0); so that the direction cosines of O P are proportional to (0, tan p, -1). Let (x, y) be any point

Q of the star's path traced on the tangent plane. The direction cosines of O Q are proportional to $(x, y, -1)$; and thus, since this line is inclined to O P at angle p we have

$$\cos p = \frac{y \tan p + 1}{\sqrt{(1+\tan^2 p)(1+x^2+y^2)}},$$

or

$$1 + x^2 + y^2 = 1 + 2y \tan p + y^2 \tan^2 p$$

or

$$y = \tfrac{1}{2} \cot p \,.\, x^2 + \cot 2p \,.\, y^2.$$

When p is small, this may be written

$$y = \frac{x^2}{2p} + \frac{x^4}{8p^3} = x\left[\left(\frac{x}{2p}\right) + \left(\frac{x}{2p}\right)^3\right]$$

all the quantities being expressed in circular measure.

The distances of wires 1 and 7 from the meridian at Greenwich are about 11′; so that for a star 1° from the pole $\frac{x}{2p} = \cdot 09$, and $\left(\frac{x}{2p}\right)^3 = \cdot 0007$; thus the second term produces an effect of $11 \times 60 \times \cdot 0007 = 0''\cdot 5$, which is quite appreciable. But at 2° from the pole this becomes $0''\cdot 06$; so that it is negligible except for close polar stars.

9. We have in the above neglected the instrumental constants c, m, n, and the inclination of the wire. The effect of the constants c, m, n is to shift the apparent origin of coordinates to the right by the quantity

$$(c + m \sin p + n \cos p) \equiv c' \text{ say},$$

assuming that c, m, n are expressed in seconds of arc, and thus we have

$$y = \tfrac{1}{2}(x - c')^2 \cot p + y^2 \cot 2p.$$

But c' is very small. The chief additional term is $-c'x \cot p$, which is eliminated in symmetrical transits (at wires 1 and 7 or 2 and 6 say), and does not therefore affect the above investigation concerning $(2+6)-(1+7)$ for instance. The constant term $\frac{1}{2}c'^2 \cot p$ is very small indeed, and in any case does not affect the above investigation.

On the Apparent Disc and on the Shadow of an Ellipsoid.

By A. Marth.

If k denotes the equatorial radius and $e = \sin \epsilon_0$ the eccentricity of a planet's ellipsoidal surface, so that the polar radius is $k \cos \epsilon_0$, the outline of the planet's disc, as seen from a point in planetocentric latitude B above the plane of the planet's equator and at the distance Δ, will be an ellipse, the semi-axes a and b of which are

$$a = \frac{k}{\Delta}\omega'' \qquad \omega'' = \frac{1}{\text{arc } 1''}$$

$$b = a\sqrt{1 - e^2 \cos^2 B} = a \cos \epsilon,$$

If, further,

$$\left.\begin{aligned} \sin \epsilon &= \sin \epsilon_0 \cos B. \\ \cos \epsilon \sin \nu &= \sin \epsilon_0 \sin B \\ \cos \epsilon \cos \nu &= \cos \epsilon_0, \end{aligned}\right\} \quad \ldots\ldots\ldots\ldots \quad (1)$$

the proportion $\cos \epsilon$ of the axes of the apparent disc is found from the proportion $\cos \epsilon_0$ of the axes of the ellipsoid by

$$\cos \epsilon = \cos \epsilon_0 \sec \nu, \text{ where } \tan \nu = \tan \epsilon_0 \sin B,$$

and $\cos \epsilon_0$ from $\cos \epsilon$ by

$$\cos \epsilon_0 = \cos \epsilon \cos \nu, \text{ where } \sin \nu = \tan \epsilon \tan B.$$

These simple formulæ for the outline of the apparent disc are only valid when the distance Δ in comparison with k is so great that terms of the second order $\frac{k^2}{\Delta} \ldots$ may be neglected. If that is not the case, strict formulæ must be substituted.

Let λ and β denote the planetocentric longitude and latitude, referred to the plane of the planet's equator, of a point on the ellipsoidal surface, $k\rho$ its linear distance from the centre of the ellipsoid, and L B Δ the corresponding coordinates of the point of view, so that L B and $k \cos \nu$ are the coordinates of the centre point of the apparent disc. Further, let $p - P = \pi$ denote the position angle of the surface point at the apparent centre of the disc, reckoned from the direction P of the polar axis, σ the planetocentric angular distance or the angle between $k\rho$ and Δ, Δ' the linear distance between the surface point and the point of view, and s the angle between Δ' and Δ. The values of $\pi\ \sigma\ s\ \Delta'$ are found by

$$\left.\begin{aligned} \sin \sigma \sin \pi &= \cos \beta \sin (L - \lambda) \\ \sin \sigma \cos \pi &= -\cos \beta \cos (L - \lambda) \sin B + \sin \beta \cos B \\ \cos \sigma &= \cos \beta \cos (L - \lambda) \cos B + \sin \beta \sin B \\ \Delta' \sin s &= k\rho \sin \sigma \\ \Delta' \cos s &= \Delta - k\rho \cos \sigma. \end{aligned}\right\} \quad \ldots \quad (2)$$

Instead of the latitudes β and B, it will be advantageous to introduce latitudes β' and B′ connected with them by

$$\tan \beta' = \tan \beta \sec \epsilon_0$$

and

$$\tan B' = \tan B \sec \epsilon_0.$$

These latitudes are the latitudes of the points, where lines passing through the surface points perpendicular to the equator cut the sphere circumscribed with radius k round the centre of the ellipsoid, or also of the points where lines perpendicular to the polar axis meet the sphere circumscribed with radius $k\cos\epsilon_0$, so that we have

$$\left.\begin{aligned} \rho \sin \beta &= \sin \beta' \cos\epsilon_0 \text{ and } \cos \nu \sin B = \sin B' \cos \epsilon_0 \\ \rho \cos \beta &= \cos \beta' \qquad\qquad \cos \nu \cos B = \cos B' \\ &\qquad\qquad\qquad\quad \sin \nu = \sin B' \sin \epsilon_0 \end{aligned}\right\} \quad . \quad . \quad . \quad (3)$$

and the equations (2) become

$$\left.\begin{aligned} \rho \sin \sigma \sin \pi &= \cos \beta' \sin (L-\lambda) \\ \rho \sin \sigma \cos \pi \,.\, \sec \epsilon &= -\cos \beta' \cos (L-\lambda) \sin B' + \sin \beta' \cos B' \\ \rho \cos \sigma \,.\, \cos \nu &= \cos \beta' \cos (L-\lambda) \cos B' + \sin \beta' \sin B' \,.\, \cos^2 \epsilon_0 \end{aligned}\right\} \quad (4)$$

In order that Δ' should be a tangent to the ellipsoid, the coordinates of the surface point, if for a few moments we introduce rectangular coordinates

$$\begin{aligned} \xi &= k\rho \cos \beta \cos \lambda & X &= \Delta \cos B \cos L \\ \eta &= k\rho \cos \beta \sin \lambda & Y &= \Delta \cos B \sin L \\ \zeta &= k\rho \sin \beta & Z &= \Delta \sin B, \end{aligned}$$

must satisfy the equation

$$1 = \frac{\xi X + \eta Y}{k\Delta} + \frac{\zeta Z}{k\Delta \cos^2 \epsilon_0},$$

or, returning to polar coordinates,

$$\frac{k}{\Delta} = \rho \cos \beta \cos (L-\lambda) \cos B + \rho \sin \beta \sin B \,.\, \sec^2 \epsilon_0,$$

or finally

$$\frac{k}{\Delta} \cos \nu = \cos \beta' \cos (L-\lambda) \cos B' + \sin \beta' \sin B' \quad . \quad . \quad . \quad (5)$$

From this equation and the equations (4), the special values of $\rho \sin \sigma'$ and $\rho \cos \sigma'$ for points of the rim are to be deduced, which, substituted in the last equation (2), furnish the corresponding values of s' and Δ'.

The sum of the squarcs of the first and second equation (4) and of (5) gives

$$\rho^2 \sin^2 \sigma \,(\sin^2 \pi + \cos^2 \pi \sec^2 \epsilon) + \frac{k^2}{\Delta^2} \cos^2 \nu = 1$$

or

$$\rho^2 \sin^2 \sigma \,(1 + \tan^2 \epsilon \cos^2 \pi) = 1 - \frac{k^2}{\Delta^2} \cos^2 \nu.$$

Therefore, putting

$$\left.\begin{aligned} \frac{k}{\Delta} \cos \nu &= \sin h \\ \tan \epsilon \cos \pi &= \tan \epsilon' \end{aligned}\right\} \quad \ldots\ldots\ldots \quad (6)$$

we have

$$\rho \sin \sigma' = \cos h \cos \epsilon'.$$

The third equation (4) and (5) gives

$$\rho \cos \sigma' = \frac{k}{\Delta} - \sin \beta' \sin B' \,.\, \sin^2 \epsilon_0 \sec \nu$$

$$= \frac{k}{\Delta} - \tan^2 \epsilon_0 \,.\, \rho \sin \beta \sin B.$$

But

$$\sin \beta = \sin \sigma \cos \pi \cos B + \cos \sigma \sin B.$$

Hence

$$\rho \cos \sigma' \,(1 + \tan^2 \epsilon_0 \sin^2 B) = \frac{k}{\Delta} - \tan^2 \epsilon_0 \,.\, \rho \sin \sigma' \cos \pi \cos B \sin B,$$

or as

$$\rho \sin \sigma' = \cos h \cos \epsilon',$$

$$\rho \cos \sigma' = \sin h \cos \nu - \cos h \sin \nu \sin \epsilon'$$

Substituting these values of $\rho' \sin \sigma'$ and $\rho \cos \sigma'$ in the last equations (2) we derive

$$\left.\begin{aligned} &\Delta' \sec h \sin s' = k \cos \epsilon' \\ &\Delta' \sec h \cos s' = \Delta \cos h + k \sin \nu \sin \epsilon' \\ \text{or} \quad &\frac{\Delta' \cos \nu}{\Delta \cos h} \sin s' = \sin h \cos \epsilon' \\ &\frac{\Delta' \cos \nu}{\Delta \cos h} \cos s' = \cos h \cos \nu + \sin h \sin \nu \sin \epsilon' \\ &\tan s' = \frac{\tan h \sec \nu \cos \epsilon'}{1 + \tan h \tan \nu \sin \epsilon'} \end{aligned}\right\} \quad \ldots \quad (7)$$

or, if preferred, indirectly

$$\tan s' = \frac{k \cos \epsilon'}{\Delta \cos h} (1 - \tan s' \sin \nu \tan \epsilon')$$

For

$\pi = \pm 90°$ ϵ' is 0 hence $\tan s' = \tan h \sec \nu$ or $= \frac{k}{\Delta} \sec h$

$\pi = \frac{0°}{180}$ $\epsilon' = \pm \epsilon$ hence $\tan s' = \frac{\tan h \sec \nu \cos \epsilon}{1 \pm \tan h \tan \nu \sin \epsilon}$

$$= \frac{k \cos \epsilon}{\Delta \cos h} (1 \mp \tan s' \sin \nu \tan \epsilon)$$

As ν has the same sign as B, the radii s' of the disc on that side of the equator, where the point of view is, are accordingly rather shorter than those on the opposite side.

If the values of λ and β of the points of the rim are required, they may be found by means of the equations

$$\left.\begin{aligned} \sec h \cos \beta' \sin (L-\lambda) &= \cos \epsilon' \sin \pi \\ \sec h \cos \beta' \cos (L-\lambda) &= -\frac{\cos \epsilon'}{\cos \epsilon} \cos \pi \sin B' + \tan h \cos B' \\ \sec h \sin \beta' &= \frac{\cos \epsilon'}{\cos \epsilon} \cos \pi \cos B' + \tan h \sin B' \end{aligned}\right\} \quad . \quad (8)$$

The formulæ thus derived for the apparent disc of an ellipsoid may now be serviceable in the investigation of the shadow problem, the strict solution of which, when pursued in this way, will be found to offer no great obstacles, even if the light-supplying body is itself an ellipsoid of any eccentricity.

A few preliminary considerations may be useful for a clearer understanding of the question at issue. Let K be the radius of the (spherical) Sun, R the distance between Sun and planet, and let the point of view be in the prolongation of R and of the axis of the shadow. While the distance of the point from the centre of the planet is Δ, its distance from the Sun is $R+\Delta$, so that the Sun's apparent disc is a circle of semi-diameter H, where $\sin H = \frac{K}{R+\Delta}$, and upon this circle the dark disc of the planet is seen projected. Let now the point of view approach the planet or let Δ be lessened till the edges of the planet in position angles $\pm 90°$ touch the rim of the Sun. The Sun appears there in the shape of two cusps, the end points of which just touch, and the inner edges of which, being formed by the outline of the ellipsoid, are not symmetrical, except when B is o, the cusp on the side of B being the broader one. By farther approaching the planet, the two discs cross, having tangents in common at the four crossing points. With Δ lessening the cusps diminish more and more, till the last rays of the Sun disappear, first on the side opposite to B, and finally at the end point of the disc's minor axis on the side of B. Now these groups of tangents, common to the two bodies at every point of the shadow axis within the indicated limits, form a continuous surface, the surface of the umbra, and it is required to determine the sections of this surface or the curves described by this surface on planes perpendicular to the shadow axis at any given points.

The angle s' between the tangent to the ellipsoid in position angle π and the shadow axis at a point at distance Δ, is found by

$$\tan s' = \frac{k \cos \epsilon'}{\Delta \cos h + k \sin \nu \sin \epsilon'},$$

the angle H between the tangent to the spherical Sun and the shadow axis by

$$\sin H = \frac{K}{R+\Delta}.$$

In order that the tangent should be common to both bodies, the distance Δ must be so determined that $s' = H$, or that

$$\sin s' = \frac{k \cos \epsilon' \cos s'}{\Delta \cos h + k \sin \nu \sin \epsilon'} = \frac{K}{R+\Delta},$$

and, therefore, that

$$\frac{k}{\Delta} = \frac{K \cos h - k \cos \epsilon' \cos s'}{R \cos \epsilon' \cos s' - K \sin \nu \sin \epsilon'}.$$

Hence we get the value of h by

$$\tan h = \frac{K \sec \epsilon' - k \sec h \cos s'}{R \sec \nu \cos s' - K \tan \nu \tan \epsilon'},$$

which, as it contains sec h and cos s', must be found indirectly if no conditions are introduced to make their differences from 1 insensible.

If r is the distance of a point of the tangent from the centre of the planet, and σ the angle between r and the shadow axis, the linear distance of the point from the axis will be

$$r \sin \sigma = (\Delta - r \cos \sigma) \tan s',$$

or as

$$\Delta \tan s' = \frac{k \cos \epsilon'}{\cos h + \sin h \tan \nu \sin \epsilon'},$$

$$r \sin \sigma = \frac{k - r \cos \sigma \,.\, \sin h \sec \nu}{\cos h \sec \epsilon' + \sin h \tan \nu \tan \epsilon'}.$$

The formulæ for finding the radii $r \sin \sigma$ of the curve formed by the umbra on a plane passing perpendicularly through the point $r \cos \sigma$ of the axis, are accordingly

$$\left.\begin{aligned} \tan \epsilon' &= \tan \epsilon \cos \pi \\ \tan h &= \frac{K \sec \epsilon' - k \sec h \cos s'}{R \sec \nu \cos s - K \tan \nu \tan \epsilon'} \\ \tan s' &= \frac{\tan h \sec \nu}{\sec \epsilon' + \tan h \tan \nu \tan \epsilon'} \\ r \sin \sigma &= \frac{k \sec h - r \cos \sigma \,.\, \tan h \sec \nu}{\sec \epsilon' + \tan h \tan \nu \tan \epsilon'} \end{aligned}\right\} \quad \ldots\ldots (9)$$

Though the assumption that the illuminating body itself is an ellipsoid has at present no practical application, I will not fail to give also the formulæ adapted to that case.

Let K be the equatorial radius and $E = \sin \eta_0$ the eccentricity of the ellipsoidal Sun, B the latitude above the Sun's equator and $R+\Delta$ the distance of the point of view in the shadow axis, and

let the position angle of the polar axis of the planet, reckoned from the direction of the polar axis of the Sun, be P, so that the position angle of a tangent to the Sun corresponding to π is $\pi+\mathrm{P}$.

Making then

$$\tan\gamma=\tan\eta_0\,.\,\sin B$$

$$\tan\eta=\tan\eta_0\,.\,\cos B\sec\gamma$$

$$\tan\eta'=\tan\eta\cos(\pi+\mathrm{P})$$

and

$$\sin\mathrm{H}=\frac{\mathrm{K}\cos\gamma}{\mathrm{R}+\Delta},$$

the angle H′ between the tangent in position angle $\pi+\mathrm{P}$ and the shadow axis will be

$$\tan\mathrm{H}'=\frac{\mathrm{K}\cos\eta'}{(\mathrm{R}+\Delta)\cos\mathrm{H}+\mathrm{K}\sin\gamma\sin\eta'},$$

and this tangent will be common to both bodies, planet and Sun, if Δ is so determined that

$$\frac{k\cos\epsilon'}{\Delta\cos h+k\sin\nu\sin\epsilon'}=\frac{\mathrm{K}\cos\eta'}{(\mathrm{R}+\Delta)\cos\mathrm{H}+\mathrm{K}\sin\gamma\sin\eta'}.$$

Accordingly the value of

$$\frac{k\cos\nu}{\Delta\cos h}=\tan h$$

is found by

$$\tan h=\frac{\mathrm{K}\cos\eta'\sec\epsilon'-k\cos\mathrm{H}\sec h}{\mathrm{R}\cos\mathrm{H}+\mathrm{K}\cos\eta'(\sin\gamma\tan\eta'-\sin\nu\tan\epsilon')}\,.\,\cos\nu$$

(the cos H involved being derived from

$$\sin\mathrm{H}=\frac{\mathrm{K}\cos\gamma}{\mathrm{R}+\left(\frac{\sin h\sec\nu}{k}\right)}),$$

and finally the radius $r\sin\sigma$ in position angle π of the curve formed by the surface of the umbra on a plane passing perpendicularly through the point $r\cos\sigma$ of the shadow axis

$$r\sin\sigma=\frac{k\sec h-r\cos\sigma\,.\,\tan h\sec\nu}{\sec\epsilon'+\tan h\sec\nu\,.\,\sin\nu\tan\epsilon'}.$$

The application of these formulæ to fictitious cases leads to a variety of interesting curves, the consideration of which I must here forego.

In the cases of *Jupiter* and of *Saturn* the computation of the sections of their shadows becomes simplified. The "Ephemerides for Physical Observations of *Jupiter*" for 1891 and succeeding years contain the longitudes $\Lambda+180°$ and latitudes B of the Sun

(referred to the plane of *Jupiter's* equator and corrected for aberration), which, when used with the "Data for Computing the Positions of the Satellites of *Jupiter*," serve in computing the jovicentric coordinates

$$r \sin \sigma \sin \pi, \qquad r \sin \sigma \cos \pi, \qquad r \cos \sigma$$

of the satellites referred to the axis of the shadow cone as the z axis, as mentioned in *Monthly Notices*, vol. li. p. 508. The distance $r \sin \sigma$ of the satellite from the axis of the shadow cone must then be compared with the corresponding radius of the section of the shadow which passes through the point $r \cos \sigma$ of the z axis. The formulæ become ($-B$ being substituted for B)

$$\tan \nu = \tan \epsilon_0 \sin B$$
$$\tan \epsilon = \tan \epsilon_0 \cos B \sec \nu$$
$$\tan \epsilon' = \tan \epsilon \cos \pi$$
$$k = \frac{K \sec \epsilon' - k}{R - K \sin \nu \tan \epsilon'}$$

(h being written for $\tan h \sec \nu$)

$$r \sin \sigma = \frac{k - h \,.\, r \cos \sigma}{\sec \epsilon' - h \,.\, \sin \nu \tan \epsilon'}.$$

In the case of the shadow of the Earth the formulæ become still simpler so far as the geometrical shadow is concerned.

Let A D be the right ascension and declination of the axis of the shadow, or of the prolongation of R, α δ the geocentric right ascension and declination of the Moon, π its parallax, or $r = \frac{1}{\sin \pi}$ its linear distance, and κ its semi-diameter expressed in semi-diameters of the Earth's equator. Further, let α d be the right ascension and declination of the Moon's centre for a spot on its surface in selenographical longitude λ and latitude β, N the node and J the inclination of the Moon's equator referred to the plane parallel to the Earth's equator, and α_0 the Moon's mean right ascension, analogous to l_0 its mean longitude ($\alpha_0 - N = l_0 - \Omega + \Delta + 180$ in Encke's notation, adopted in the *Nautical Almanac*, N and J being the Ω' and i, v. *Monthly Notices*, vol. xli. p. 420 ff.) The formulæ for finding the coordinates of the spot λ β referred to the shadow axis are

$$\sec \beta \cos d \sin (\alpha - N) = \sin (\alpha_0 - N + \lambda) \cos J + \tan \beta \sin J$$
$$\sec \beta \cos d \cos (\alpha - N) = \cos (\alpha_0 - N + \lambda)$$
$$\sec \beta \sin d = \sin (\alpha_0 - N + \lambda) \sin J - \tan \beta \cos J$$

$$x = r \cos \delta \sin (\alpha - A) \qquad \xi = \kappa \cos d \sin (\alpha - A)$$
$$y = r \sin (\delta - D) + x \tan \tfrac{1}{2} (\alpha - A) \sin D \qquad \eta = \kappa \sin (d - D) + \xi \tan \tfrac{1}{2} (\alpha - A) \sin D$$
$$z = r \cos (\delta - D) - x \tan \tfrac{1}{2} (\alpha - A) \cos D \qquad \zeta = \kappa \cos (d - D) - \xi \tan \tfrac{1}{2} (\alpha - A) \cos D$$

Hence the position angle p of the spot, its angular distance σ from the shadow axis and its linear distance r' from the Earth's centre are

$$r' \sin \sigma \sin p = x - \xi$$
$$r' \sin \sigma \cos p = y - \eta$$
$$r' \cos \sigma \quad = z - \zeta.$$

If $\cos \epsilon_0$ is the proportion of the Earth's polar axis to the diameter of the equator

$$\sin \epsilon = \sin \epsilon_0 \cos D$$
$$\tan \epsilon' = \tan \epsilon \cos p$$
$$h = \frac{K - k}{R},$$

the radius of the section of the geometrical umbra is

$$r' \sin \sigma = \cos \epsilon' - h \,.\, r' \cos \sigma.$$

But the observed enlargement of the shadow proves that while a lunar spot near the border of the shadow receives still, or receives already, direct sunlight from a cusp outside the Earth's atmosphere, this illumination is so feeble that, as seen from the Earth, it merges into the dim illumination produced by the broken sunlight passing through the atmosphere and surrounding part of the Earth's disc. The uncertainty in fixing upon what ought to be considered the true border-line of the full shadow leaves it doubtful how much of the light near the margin of the Sun is to be treated as practically ineffective, or how much the value of K must be diminished in order to furnish the border-line. If I am not prevented from preparing ephemerides for physical observations of the Moon for 1898, I intend to give, for a number of lunar spots, predictions of the approximate times of their crossing the border-line of the shadow during the three lunar eclipses of that year, in the hope that many observers may join in making contributions for the closer examination of the question.

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The Orbit of δ Cygni. By S. W. Burnham.

The companion to δ *Cygni* was discovered by Sir William Herschel on 1783 September 20. The angle was measured, but all we know of the distance of the components at that time is found in his description of the appearance of the star in his reflector. Herschel says, "With 278 about $\frac{1}{2}$-diameter of L [large star]; with 460 $\frac{3}{4}$-diameter of L; with 932 full $1\frac{1}{2}$-diameter of L in hazy weather, which has taken off the rays of

L, and thereby increased the interval. Position, 18° 21′ *nf.*; perhaps a little inaccurate."

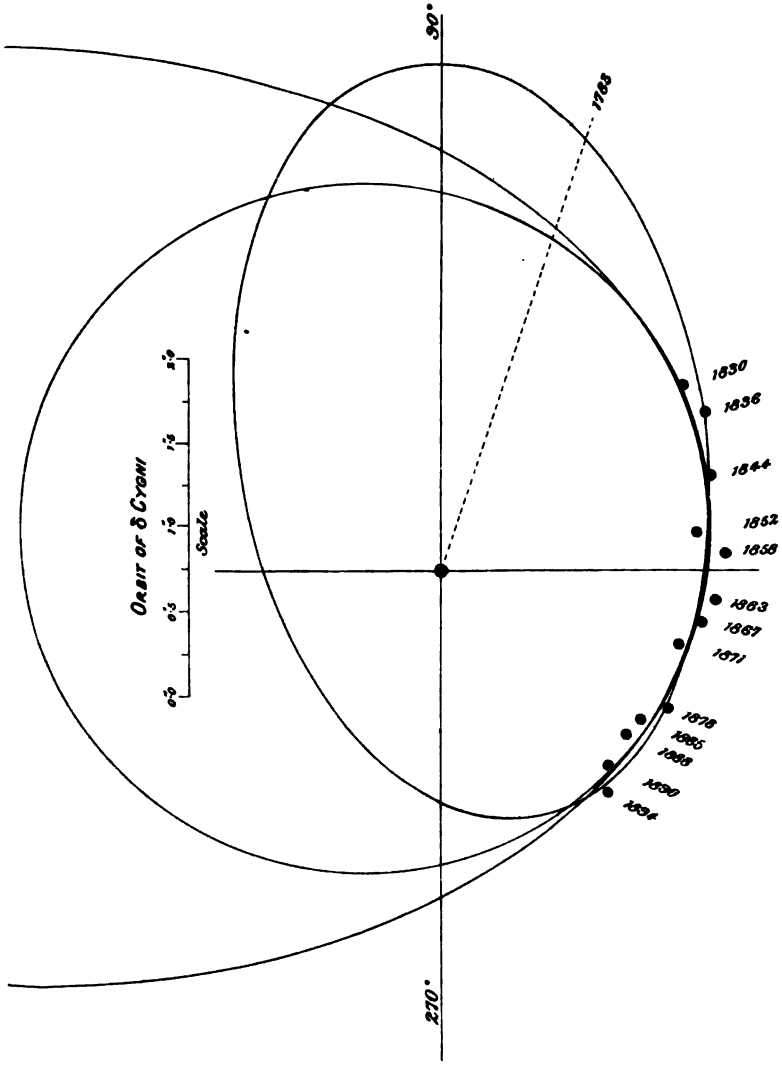
In the early part of the present century, Herschel examined this star several times, but could not see the companion. Referring to the matter at this time (*Phil. Trans.* 1804), he says:

"This double star, I believe, has furnished us with a second instance of a conjunction resembling that of ζ *Herculis*. The position, 1783 September 22, was 18° 21′ *nf.* 1802 January 3, 10 and 11, I could no longer perceive the small star, which must have been at least so near the large one as to be lost in its brightness. 1804 January 29, I examined this star with powers from 527 to 1500, and saw it as a lengthened star, but not with sufficient clearness to take a measure of its position. 1804 May 22, in a very clear evening, I tried 527 and 1500 with the 10-foot reflector, which acted remarkably well on the double stars, but I could not perceive the small star of δ *Cygni*. . . . A parallactic motion of δ will perfectly account for this occultation, for the situation of the two stars in 1783 was such that this motion must have carried the large star by this time nearly upon the small one."

It had been stated that Herschel was not able to see the companion at any time after his first observation, although he looked for it several times in the early years of this century; but Sadler has examined his MS. now in the Royal Astronomical Society (*Observatory*, September 1886), and given extracts from it relating to his observations in 1802–3–4, from which it appears that this star was seen double at least once on 1803 May 28, with the 7-foot reflector, and noted, "near ½-diameter of smaller. The diameters are full 2 to 1."

These and other failures to see the companion, taken in connection with the opinion of Herschel that the star had actually become single, led to many erroneous ideas concerning the supposed rapid motion. Struve thought that more than a whole revolution had been performed between 1783 and the commencement of his observations in 1826, and that the period was less than 40 years.

It soon became apparent that the motion was very slow and practically uniform, and that there had been but little, if any, change in the distance from the time of discovery. The failures to see the companion were then frequently charged to variability in its light, and this notion is still entertained by some observers. Judging from my own experience with this and similar unequal pairs in the last twenty years, and considering the value of negative evidence in matters of this kind, there is nothing whatever to warrant even a suspicion that there has been at any time any sensible variation in the magnitude of the companion. Dawes was sceptical as to the alleged variability, and said that "great allowance must be made for the effect on such an object of different conditions of the atmosphere"; and that he had


90°
1788
1850
1856
1844
1862
1858
1863
1867
1871
1878
1885
1888
1890
1894
270°
Orbit of δ Cygni
Scale
0·5
1·0
1·5
2·0

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"never viewed this star under a moderately favourable state of the air without seeing the small companion plainly enough with apertures from 6½ to 8¼ inches." In a pair of this class, the widely differing estimates of the magnitude of the smaller star by different observers is no evidence of any change in its brightness. Such double stars are frequently not seen with small apertures which under proper conditions show the companion well.

Four orbits have been computed for this pair in the last fifty years. The dates of the last measures used are given in the first column :—

1842	Hind	178·7 years	*A. N.* 565
1856	Behrmann	280·56 „	*A. N.* 1517
1865	Behrmann	415·11 „	*A. N.* 1561
1887	Gore	376·66 „	*Mon. Not.* L, 398

How few data were available in 1842, when the arc described from Struve down to that time was only about 15°, and there was nothing else but a rough single measure of the angle which did not purport to have any great value, is too obvious to require comment here. If Herschel's angle had been supplemented with the distance, and in both the highest accuracy had been reached which is attainable by a mean result from measures on a large number of nights by the best modern appliances, there still would have been nothing in the material to limit the arc representing these positions to a single ellipse, or to several wholly dissimilar ellipses. The material in 1856 for all practical purposes was no better, although the position-angle had changed a few degrees in the interval of fourteen years. Behrmann gave an ephemeris to 1880, and it is not surprising to find that it turned out, when the real position of the companion was determined, that the calculated place for the last-named date was 170° in error. Nine years later, with a few degrees of further change in the angle, he made a new investigation and obtained the second orbit given above, finding an entirely different ellipse, and increasing the period 135 years. This represents Herschel's angle of 1783 without error, and makes the distance at that time 2″·56. Gore's orbit also satisfies this angle within 0°·7, and makes the distance 2″·72.

On the accompanying diagram (Plate 10) I have given the angle of Herschel and thirteen repeatedly measured positions by leading observers at short intervals down to the present time. Of course many other measures might be included, but they would serve no purpose so far as the present question is concerned, and add nothing to the weight of the evidence bearing upon the orbit of this system. In fact, putting in all the measures, good, bad, and indifferent, would only exaggerate the uncertainty about this star, which is already sufficiently apparent from a use of the best material only.

I have shown on the diagram three possible orbits of this system, not with the idea or purpose of adding anything to our knowledge of the motion, but rather to emphasise the wholly indeterminate character of the problem presented. The arcs of the large ellipse and the circle are identical so far as the complete measures are concerned, and represent these positions as perfectly as they are ever likely to be represented, even when a complete revolution has been performed. The accuracy with which the measures are represented by these two entirely different orbits will appear from the following corrections to the observed positions.

	°	″		
1830·21	+0·1	−0·02	6n	⧖.
1836·52	+0·1	−0·09	4n	⧖.
1844·78	+0·8	−0·03	3n	O⧖.
1852·70	+1·3	+0·08	3n	O⧖.
1858·71	−1·3	−0·09	3n	O⧖.
1863·74	+0·7	−0·07	3n	O⧖.
1867·60	+0·2	−0·02	7n	△.
1871·69	−0·3	+0·05	9n	△.
1878·59	+2·5	−0·05	3n	△.
1885·73	−2·8	+0·06	4n	Hl.
1888·93	−3·4	+0·08	4n	Hl.
1890·57	+1·5	+0·03	4n	Hl.
1894·84	−0·8	−0·07	11n	Com.

These observations can also be represented precisely as well by an ellipse with the principal star outside altogether.

The smaller ellipse differs but little from the other figures, and for all practical purposes represents the measures equally well, since the largest distance variation does not exceed 0″·08. In this ellipse the distance in 1783 would be 2″·68, and the correction to the angle of Herschel is only 0°·5. And yet, aside from the short arc represented by the measures from 1830 to 1894, which is practically identical in all, these three orbits have nothing in common either as to the period or any other element.

The large ellipse gives a period of 1040 years, the circle 420 years, and the small ellipse 300 years. The true period may be anywhere between these limits, or perhaps outside of both. It must be remembered that in dealing with a short arc the agreement of observed and computed positions, however close and satisfactory it may be, does not even tend to prove that the orbit so found is correct, or anything like the real orbit. It is doubtful if the measures of another hundred years will be sufficient to determine the period of this pair to a reasonable approximation.

The Orbit of Sirius. By S. W. Burnham.

With the addition of the recent measures of the companion to *Sirius*, we have data for defining the orbit within narrow limits of error. Previous to this time all the orbits of this system have been based upon a short arc described by the companion from 37° to 85°, and this, with the errors of observation which are necessarily found in all micrometrical work, is of itself insufficient for even an approximate result, since the observed positions of so short an arc can be equally well represented by many ellipses having little in common. Most of the computers doubtless have been more or less influenced in the selection of the ellipse to represent the apparent orbit by the period of the theoretical disturbing body as deduced from the variable proper motion shown in the meridian observations. In this instance that would result in the adoption for the apparent orbit of nearly the smallest ellipse which would represent the short arc of the observed positions. Consequently, of the twelve orbits which have been computed since 1880, using the measures up to the respective dates, with periods from 49·5 to 58·5 years, only three of them exceed 52·2 years, and most of them are not more than a year or two from the theoretical time.

The companion was last measured previous to 1896 by the writer with the 36-inch refractor at the Lick Observatory in the early part of 1890. Satisfactory measures were secured on several nights although the companion was seen with considerable difficulty. In the latter part of the same year, and again in the following year, it was invisible under the best conditions; and Barnard in the two or three succeeding years was unable to see the small star with the same instrument.

All subsequent attempts to see the companion at Mount Hamilton and elsewhere with the largest telescopes down to 1896 October, resulted in failure. Two observers at the Lick Observatory, Hussey and Campbell, have placed on record the invisibility of the companion with the 36-inch on six nights in 1896 February and March. As it is stated that the atmospheric conditions on each night were good, and *Sirius* near the meridian in all the observations, it is probable that this failure to see the small star was due to the inexperience of the observers in double-star work, since it was easily found by Aitken with the same instrument less than eight months later, when the distance could not have increased more than 0″·2. Any form of orbit which would permit of a rapid increase in the distance at this point would be inconsistent with the prior measures.

The arc passed over by the companion from 1890 to 1896 is 170°, so that altogether we have a path of 255° for the motion of the companion since its discovery in 1862 by Alvan G. Clark;

and this should be sufficient for the determination of the elements of the orbit with only a small percentage of error.

In my papers on *Sirius* in *Monthly Notices* for 1891 April and November, and 1893 June, I have collected and arranged in chronological order all the measures of the companion from its discovery down to my last measures in 1890; and from these observations have deduced twenty-nine yearly means for the position of the companion for each year from 1862 to 1890. These means were made with all possible care, and with due reference to the probable relative value of the individual sets of measures, based upon the number of nights, the experience of the observer in micrometrical and double-star work, the instrument used, and the apparent general value of the several series of measures when considered as a whole. This was all done in advance of any use of the observations for obtaining the orbit, and therefore wholly independent of any prejudice or theory concerning the period or anything else. From these yearly positions I found the apparent orbit given in the first paper referred to. The complete elements (*Mon. Not.* liii. 482; *Pub. Lick Observatory*, ii. 54, 239) are as follows:—

$P = 51{\cdot}97$ years.	$i = 50°{\cdot}8$
$T = 1893{\cdot}5$	$\Omega = 40°{\cdot}3$
$e = 0{\cdot}568$	$\lambda = 135°{\cdot}4$
$a = 8''{\cdot}31$	

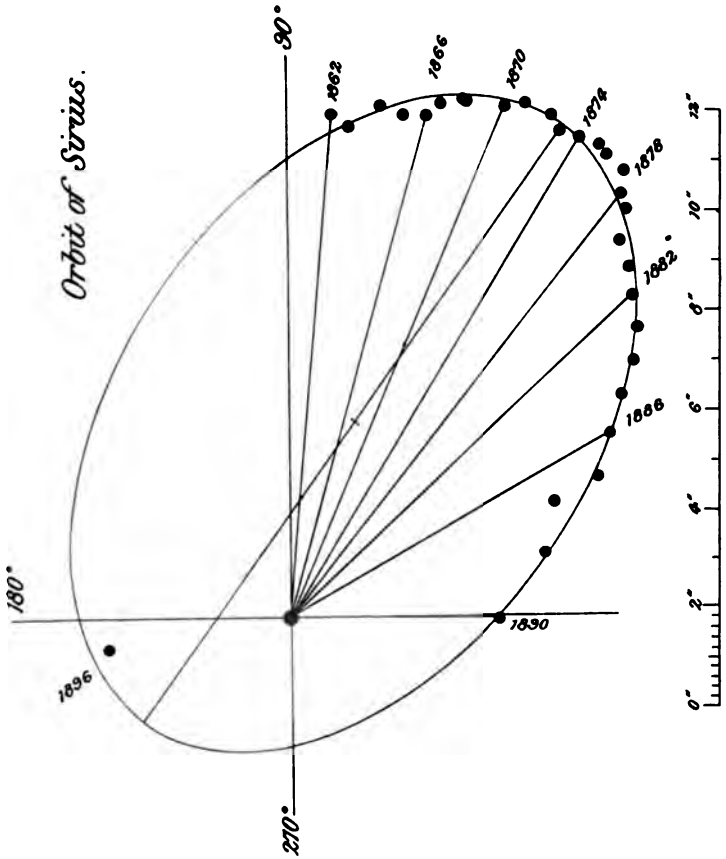
The fact that the companion could not be seen with the 36-inch in 1891, only six months after it had been measured in the early part of that year, was a certain indication that the form of the orbit in the fourth quadrant must be such as to require a rapid diminution in the distance of the companion at that point; and therefore, as stated in my paper at the time, nearly the smallest ellipse that would properly represent the measures was adopted as the most probable orbit. But for this consideration there was nothing to justify the investigation at all from such data, since an orbit with a period of several years more would have been equally probable, and would have represented the measures down to that time equally well.

The accompanying diagram (Plate 11) shows the yearly positions referred to, and the apparent orbit now determined from a careful consideration of all the available data. The only addition to the measures used in the former orbit is the following position derived from the measures on six nights by Aitken and Schaeberle, at Mount Hamilton:—

1896·85	189°·3	3''·71

From this ellipse I find the following elements:—

$P = 51{\cdot}80$ years.	$i = 44°{\cdot}7$
$T = 1893{\cdot}77$	$\Omega = 37°{\cdot}2$
$e = 0{\cdot}600$	$\lambda = 135°{\cdot}7$
$a = 7''{\cdot}62$	


Orbit of Sirius.
90°
180°
270°
1862
1866
1870
1874
1878
1882
1886
1890
1896
12"
10"
8"
6"
4"
2"
0"

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Apparent orbit :—

Length of major axis =	14°·48
Length of minor axis =	9″·32
Angle of major axis =	54°·4
Angle of periastron =	251°·9
Star from centre =	4″·09

In the following table will be found the corrections to the observed positions as required by the final orbit :—

	°	″		°	″
1862·20	−0·5	−0·20	1877·18	+0·4	−0·30
1863·22	−1·4	+0·14	1878·12	0·0	−0·07
1864·20	−0·2	−0·10	1879·02	−0·2	−0·09
1865·22	0·0	+0·20	1880·18	−1·0	+0·08
1866·21	+0·2	+0·30	1881·19	−0·5	+0·01
1867·17	−0·4	+0·18	1882·12	0·0	+0·01
1868·16	0·0	−0·01	1883·14	+0·6	−0·01
1869·17	−2·0	+0·17	1884·22	−0·1	0·00
1870·15	−0·2	+0·04	1885·19	−0·8	−0·08
1871·21	0·0	−0·01	1886·14	+0·6	+0·04
1872·22	+0·8	−0·10	1887·19	+0·5	−0·09
1873·21	+0·3	+0·12	1888·24	−4·1	+0·18
1874·19	+0·08	+0·02	1888·97	−0·1	+0·03
1875·22	+0·7	−0·18	1890·27	0·0	0·00
1876·22	+0·3	−0·19	1896·85	+1·3	+0·29

It will be seen that this differs but little from the orbit previously found. The change in the period is less than two-tenths of a year. Aside from the position of the companion in 1896 as required by this orbit, I have no doubt that the distance of that year was undermeasured, and that it will be found hereafter that the above tabular correction is not too large. Remembering the appearance and difficulty of the companion in 1890 with the same instrument, when the distance could not have been much less than 4″·2, and the fact that I failed to see the companion at all a few months later, it appears to be improbable that the distance in 1896 was less than 4″.

The following is a short ephemeris of the companion :—

	°	″		°	″
1898·20	172·5	4·4	1900·20	151·0	4·9
1899·20	161·0	4·6	1901·20	141·1	5·2

With the extended arc given by the measures of 1896, there is but little latitude in the selection of the apparent ellipse. Of course, everything depends upon the substantial accuracy of the

last position, and especially with reference to the angle, because all the preceding positions can be represented by other ellipses. If the correctness of this position is confirmed by future measures, as it doubtless will be, there can be little change in these elements.

A New Quadruple Stellar System. By R. T. A. Innes.

The star κ *Toucani* was discovered to be double by Sir John Herschel on the night of 1834 November 3 with his 18-inch reflecting telescope. He remarks, "Very beautiful, excellent and careful measures with power 320 and triangular aperture."

His reflector measures are—

1834·84	12°·0	2″	6½ and 9
1834·90	11·3	2½	6 „ 9

He measured it again in 1836 with his 5-inch refractor, getting

1836·64	17°·8	5″·78	5½ and 11
1836·91	14·2	4·24	6½ „ 10

Amongst later measures may be cited

1871·9	0°·0	5″·19	H. C. Russell, Sydney.
1894·9	354·8	5·52	John Tebbutt, Windsor, N.S.W.

The comparison is also to be found in the Cordoba General Catalogue, being called 7th magnitude there.

The magnitudes may be taken as 5·6 and 7·8, the companion being of a purple colour.

The above measures alone would not prove physical connection, but the large proper motion of κ *Toucani* 0″·407 towards 86°·2 puts it beyond doubt.

The star Lac. 353, mag. 7·3, is 5′ 20″·0 north preceding κ *Toucani*. Whilst observing it in 1895 with a reflecting telescope made by Mr. F. Dixon Edmonds, an amateur, residing in Sydney, I noticed that it was also a double star (No. 27 of the list given on p. 262 of vol. vi. of the *Journal of the British Astronomical Association*).

An estimate made at that time gave

1895·8 180° 1″ ±

and one made here with the 7-inch refractor is

1896·8 185° 1″·4 ±

magnitudes 7·7 and 8·7.

I have since found that this pair shares in the proper motion of *κ Toucani* and its companion.

As the older catalogues are not very accurate I have preferred to exhibit the results given in this way. From the recorded positions of Lac. 353 I have subtracted the positions given in the same catalogues of *κ Toucani*, getting for the equinox of 1900.

		Δ α	Δ δ	Proper Motion of *κ Toucani* since 1752. α	δ
		s	′ ″	s	″
Lacaille	1752	−46·57	+3 46·1	+ 0·00	+ 0·0
Brisbane	1825	−47·37	3 15·9	5·53	6·1
Cape	1835·8	...	3 24·1	6·34	7·0
Gilliss	1851·9	−46·24	3 21·9	7·57	8·4
Cape	1874·8	−46·59	3 23·9	9·30	10·2
Cordoba	1875·0	−46·32	3 23·4	9·31	10·3
	1896·9	−46·71	3 23·1	10·97	12·1

The differences for 1896·9 result from a comparison with *κ Toucani* with the 7-inch equatorial, Lac. 353 being found in no later catalogue than the C. G. Arg.

The proper motion of *κ Toucani* used is +0ˢ·0757 in R.A. and +0″·0835 in Dec.; in this determination, which is a preliminary one, recent Cape meridian observations have been included.

If Lac. 353 had no proper motion its distances from *κ Toucani* should have been as follows—starting from 1752 :—

	Δ α	Δ δ		Δ α	Δ δ
	s	′ ″		s	′ ″
Lacaille	−46·57	+3 [46·1]	Cape	−55·89	+3 13·7
Brisbane	52·90	3 [9·8]	Cordoba	55·63	3 13·1
Cape	...	3 17·2	1896·9	57·68	3 11·0
Gilliss	53·81	3 13·6			

Hence we may reasonably infer that the pairs *κ Toucani* and Lac. 353 are physically connected. I know of no similar system.

The circumstances of these stars give some hopes of a measurable parallax.

Finally, it will be obvious that when the periods of both pairs are known, the common period of the system will be found as soon as the direction of motion of one pair around the other is known.

Royal Observatory, Cape of Good Hope:
1897 *February* 24.

On the determination of the Epoch-Correction of an adopted system of Right Ascensions of Clock Stars from observations of the Sun, including the effects of personalities; and applications of the results to the determination of the errors of the Tables of the Sun and Moon. By E. J. Stone, M.A., F.R.S., Radcliffe Observer.

There are few points in practical astronomical work which involve more delicate considerations than those connected with the determination of the absolute corrections required by the right ascensions of our Clock Stars, and the determination of the errors of the Tables of the Sun in longitude. I propose to give in the present paper some results on this subject to which I have been led, and some practical applications.

In an investigation of this kind it is necessary to accurately define the physical meanings of the symbols employed; and the notation which I have adopted is as follows:—

θ, λ, ω denote the longitude and latitude of the Sun's centre, and the "Obliquity of the Ecliptic," computed from a set of Solar Tables with an assigned value of the variable, t.

$\theta+\delta\theta$, $\lambda+\delta\lambda$, $\omega+\delta\omega$ denote the corresponding exact values.

α, Δ denote the corresponding tabular R.A. and N.P.D. computed in the usual way from the values of θ, λ, ω.

α', Δ' are the R.A. and N.P.D. of the Sun's centre as found directly from observation; and to which the variable, t, with which the tabular places are computed, is assumed to correspond.

$\alpha'+x$, $\Delta'+y$ are the exact values of the R.A. and N.P.D.

θ', λ' are the longitude and latitude of the Sun's centre from observation as found from α', Δ', and ω.

$\theta'+\delta\theta'$, $\lambda'+\delta\lambda'$ are the exact values of the longitude and latitude of the Sun's centre.

We have, therefore, $\theta+\delta\theta=\theta'+\delta\theta'$; $\lambda+\delta\lambda=\lambda'+\delta\lambda'$ identically.

The systematic errors in R.A., x, with which we shall be principally concerned arise from

(1) Errors in the adopted R.A. of the clock stars.

(2) Differences in personalities in the observations of transits of stars and limbs of the Sun.

The systematic errors in N.P.D., y, will be chiefly due to

(3) Errors in the adopted latitudes of the observing stations.

(4) Uncorrected division-errors of the circles.

(5) Personalities on the part of the observers.

(6) Errors of the adopted refraction tables.

We shall neglect the squares and products of the small angles $\delta\theta$, δ, λ, $\delta\lambda$, $\delta\omega$, x, and y; and we then have

$$(7)\quad \alpha'+x=\alpha+\frac{\cos\omega}{\sin^2\Delta}\delta\theta-\frac{\sin\omega}{\sin^2\Delta}\sin\theta\,.\cos\theta\,.\,\delta\omega-\frac{\sin\omega}{\sin^2\Delta}\,.\cos\theta\,.\,\delta\lambda,$$

$$(8)\quad \Delta'+y=\Delta-\frac{\sin\omega}{\sin\Delta}\,.\cos\theta\,.\,\delta\theta-\frac{\cos\omega}{\sin\Delta}\,.\sin\theta\,.\,\delta\omega-\frac{\cos\omega}{\sin\Delta}\,.\,\delta\lambda,$$

or, putting $\alpha-\alpha'=f$, $\Delta-\Delta'=e$, we have

$$(9)\quad x=f+\frac{\cos\omega}{\sin^2\Delta}\,.\,\delta\theta-\frac{\sin\omega}{\sin^2\Delta}\,.\sin\theta\,.\cos\theta\,.\,\delta\omega-\frac{\sin\omega}{\sin^2\Delta}\,.\cos\theta\,.\,\delta\lambda,$$

$$(10)\quad y=e-\frac{\sin\omega}{\sin\Delta}\cos\theta\,.\,\delta\theta-\frac{\cos\omega}{\sin\Delta}\,.\sin\theta\,.\,\delta\omega-\frac{\cos\omega}{\sin\Delta}\,.\,\delta\lambda,$$

where $\frac{f''}{15}$ and e'' will be the errors of the Solar Tables in R.A. and N.P.D., as found directly from observation.

It is these tabular errors in R.A. and N.P.D., and the errors in longitude and latitude deduced from them, which are given in the published results of the Observatories at which solar observations are made.

The values of x, y, $\delta\omega$, $\delta\lambda$, and $\delta\theta$ have to be found from a discussion of equations of the form (9) and (10), or from others which are deducible from them; and one of the chief practical difficulties of the problem of finding these and the other constants involved in the expressions of the solar coordinates is connected with the necessity for the separation of any constant correction, x, required by the observed R.A. from any existing constant error, or slowly changing errors, in the Solar Tables in longitude. The equations

$$(11)\quad \delta\lambda+x\sin\omega\,.\cos\theta+\delta\omega\sin\theta+y\frac{\cos\omega}{\sin\Delta}=f\,.\sin\omega\,.\cos\theta+e\frac{\cos\omega}{\sin\Delta},$$

$$(12)\quad \delta\theta=-f\,.\cos\omega+e\frac{\sin\omega}{\sin\Delta}\,.\cos\theta+x\cos\omega-y\frac{\sin\omega}{\sin\Delta}\,.\cos\theta,$$

which are directly deduced from (9) and (10), will be found more convenient for our purpose than those equations.

If the Errors of the Tables in Ecliptic Polar Distance and Longitude, as deduced from the observed R.A. and N.P.D., and the tabular obliquity are denoted by E and L respectively, we have

$$\mathrm{E}=f\,.\sin\omega\,.\cos\theta+e\frac{\cos\omega}{\sin\Delta};\quad \mathrm{L}=f\cos\omega-e\frac{\sin\omega}{\sin\Delta}\,.\sin\theta;$$

and, therefore,

$$(13)\qquad \delta\lambda+x\,.\sin\omega\,.\cos\theta+\delta\omega\,.\sin\theta+y\frac{\cos\omega}{\sin\Delta}=\mathrm{E},$$

$$(14)\qquad \delta\theta=-\mathrm{L}+x\,.\cos\omega-y\frac{\sin\omega}{\sin\Delta}\,.\cos\theta.$$

The equations of the form (13) are independent of $\delta\theta$; and because such is the case we are able to separate the constant, x, from any existing constant error of the Solar Tables in longitude by finding x from (13). We need not discuss here the cause or causes which may give rise to such errors.

The necessity of treating the equations (9) and (10) simultaneously in order to determine x and $\delta\vartheta$ has been frequently overlooked; and erroneous results have sometimes been obtained by the violation of this condition. If we denote the mean error in longitude of the Solar Tables in use for the observations of the year by $\delta\vartheta_0$; the use of the equation (9) independently of (10) would give sensibly the value $x'=x-\frac{\delta\theta_0}{\cos\omega}$ instead of x; and the use of x' instead of x in the equation (14) would give the errors of the Tables in longitude sensibly cleared from any existing mean error, $\delta\theta_0$, whatever Solar Tables were in use: for

$$\delta\theta=-\mathrm{L}+x\cos\omega-y\frac{\sin\omega}{\sin\Delta}.\cos\theta=-\mathrm{L}+x'.\cos\omega+\delta\theta_0-y\frac{\sin\omega}{\sin\Delta}.\cos\theta$$

$$\therefore\ \delta\theta-\delta\theta_0=-\mathrm{L}+x'\cos\omega-y\frac{\sin\omega}{\sin\Delta}.\cos\theta.$$

Before, however, we can separate the angles $\lambda+\delta\lambda$ and $\omega+\delta\omega$, we have to define what is meant by the plane of the Ecliptic.

The Ecliptic in practical astronomical work is selected so that the Sun's centre merely oscillates above and below that plane; and the expression for the Sun's latitude $\lambda+\delta\lambda$, when measured from the "Ecliptic," is an exceedingly small angle which contains no terms of the form

$$\mathrm{C}+\mathrm{A}\sin.\theta+\mathrm{B}.\cos\theta \tag{15}$$

where C, A, and B are *constants*.

The small changes of latitude expressed by terms of this form, and the small secular changes which exist when the plane of reference is a fixed plane, are in practice thus thrown upon the longitude of the node and inclination of the moving plane of reference, the "Ecliptic."

On account of the importance of the equations (13) and (14), it may perhaps be worth while to obtain them directly without the introduction of the errors of the Tables in R.A. and N.P.D. We have with the adopted notation

$$\sin(\lambda'+\delta\lambda')=\cos(\omega+\delta\omega)\cos(\Delta'+y)-\sin(\omega+\delta\omega)\sin(\Delta'+y).\sin(\alpha'+x) \tag{16}$$

$$\tan(\theta'+\delta\theta')=\sin(\omega+\delta\omega)\cot(\Delta'+y).\sec(\alpha'+x)+\cos(\omega+\delta\omega).\tan(\alpha'+x) \tag{17}$$

$$\sin\lambda'=\cos\omega.\cos\Delta'-\sin\omega.\sin\Delta'\sin\alpha' \tag{18}$$

$$\tan\theta'=\sin\omega.\cot\Delta'.\sec\alpha'+\cos\omega.\tan\alpha'. \tag{19}$$

In these equations the only tabular quantity is ω.
These equations lead at once to the following

$$\delta\lambda' = -\sin\omega \,.\, \cos\theta' \,.\, x - \delta\omega \,.\, \sin\theta' - y\frac{\cos\omega}{\sin\Delta'} \tag{20}$$

$$\delta\theta' = x\cos\omega - y\frac{\sin\omega}{\sin\Delta'} \,.\, \cos\theta'. \tag{21}$$

But we have $\lambda + \delta\lambda = \lambda' + \delta\lambda'$: $\theta + \delta\theta = \theta' + \delta\theta'$ identically.
We can find λ' and θ' from (18) and (19), and then by a direct comparison between them and the tabular quantities λ and θ, we have

$$\theta - \theta' = \mathrm{L}, \text{ and } \left(\frac{\pi}{2} - \lambda\right) - \left(\frac{\pi}{2} - \lambda'\right) = \lambda' - \lambda = \mathrm{E}$$

$$\therefore \delta\lambda' = \delta\lambda - \mathrm{E} \qquad\qquad \delta\theta' = \delta\theta + \mathrm{L};$$

and, as before,

$$\delta\lambda + x \,.\, \sin\omega \,.\, \cos\theta' + \delta\omega \,.\, \sin\theta' + y\frac{\cos\omega}{\sin\Delta'} = \mathrm{E} \tag{13}$$

$$\delta\theta = -\mathrm{L} + x\cos\omega - y\frac{\sin\omega}{\sin\Delta'} \,.\, \cos\theta'. \tag{14}$$

In the equation (14) the term $x\cos\omega$ introduces a constant error into our determinations of the corrections required by the Tables in longitude, and the term $-y\dfrac{\sin\omega}{\sin\Delta}\cos\theta'$ affects the determination of the longitude of the perigee. It would appear that these corrections, if determinable with any close approximation to their true values, should be applied before attempts are made to correct the errors of the Tables.

When the equation (13) is thus found, it perhaps brings more clearly before the mind that, since the expression for the latitude $\lambda + \delta\lambda$ contains no terms of the form (15), the errors in Ecliptic Polar Distance, E, can contain the effects of no terms of this form except those due to the errors in R.A., N.P.D. and obliquity, x, y and $\delta\omega$; and that any required *constant* corrections x, $\delta\omega$, and y can thus be found from the equation

$$x\sin\omega\cos\theta + \delta\omega \,.\, \sin\theta + \frac{y\cos\omega}{\sin\Delta} = \mathrm{E} \tag{22}$$

by confining our attention to the effects of terms of the required form and suitably grouping the errors in Ecliptic Polar Distance ; but the existence of any sensible errors, $\delta\lambda$, will to some extent increase the errors of the determinations of the constants x, $\delta\omega$, and y as thus found from observation.

If all the observations during a year were made by the same person, we might assume without serious error that x and y would be constants so far as the personalities of the observer were concerned : and, therefore, if we included the mean effects of the errors of the refraction tables and uncorrected division-errors with those of the personalities of the observer in N.P.D.,

we should have x and y constants for all the observations of a year.

A discussion of the equations (22) when the observations of the Sun were fairly distributed over the year would then lead to fairly approximate values of the constants x, $\delta\omega$, and y. But, on account of x being multiplied by a small factor 0·398 ; the existence of small errors, $\delta\lambda$, which have been neglected ; and the magnitude of the chance errors of observation in the case of the Sun ; the probable errors of the determinations of the important constant, x, will not, even in the case of a single observer, be inconsiderable.

But in practice it is difficult to secure the condition that all the observations of the year should be made by the same person, and if more than one person be engaged on the observations we have to meet the difficulty that the constants, x, are not the same for all observers.

The plan which has been followed at Greenwich for many years, and which I have adopted at Oxford, has been to ignore the differences between the constants x and y due to personal peculiarities ; and thus to obtain an approximation to the average values of the constants for the observers, and of the mean error of the Solar Tables in longitude. If the observations were thoroughly well distributed amongst the different observers over the whole year, and numerous enough to destroy the effects of chance errors of observation, the results thus found would be close approximations to the truth ; but in practice the required distribution is rarely secured, and the probable errors of the determination of the required constants for each year are thus greatly increased. The effects upon the errors of the tables in longitude of the discordances between the values of x thus found for different years without change of instrument, right ascensions of clock stars, or observers, are comparable in magnitude with the errors of the Solar Tables now in use ; and, because such is the case, it has not been usual to directly apply the corrections x, y, and $\delta\omega$, found for each year, to the errors in ecliptic polar distance and longitude deduced from the uncorrected observations in R.A. and N.P.D. But the means corrections for $\frac{x''}{15}$ found from the observations of several years are applied as a correction to the R.A. of the fundamental stars every few years when an independent standard catalogue is formed ; corrections for $\delta\omega$ are applied at intervals when the correction has become sufficiently large to render this desirable, and the effects of the constant y are usually neglected.

This method of dealing with the difficulty certainly prevents any serious accumulation of errors either in the right ascensions of the stars or in the errors of the solar tables ; but it can hardly be considered as perfectly satisfactory.

The personal differences in observing transits of stars and of the Sun between the three observers at Oxford happen to be

well marked. This affords facilities for testing the practicability of separating the personalities of the observers from the errors of the solar tables; and I have, therefore, separated the observations of the Sun made by Messrs. Wickham, Robinson, and Bellamy, 1884–1891. The values of the constants thus found for each observer from the observations of the different years must be expected to be rather discordant from the paucity of the observations and the unfavourable distribution of the observations in some of the years; but the mean results for several years should be fairly reliable. At all events, I have thought the point worth a trial, and the results will be found in Table (*a*).

Radcliffe Observations of the Sun, 1884–1891.

TABLE (*a*).

Year.	No. of Obs.	(x . sin ω).	$\delta\omega$.	y.	δa.	Error of Longitude (Tabular *minus* Observed).	Error of Longitude (Tab.−Obsd.) corrected for mean values of x for each observer.
				Observer W.			
					s		
1884	23	+0.717	+0.785	−0.112	+0.120	+1.436	+0.422
1885	32	+0.349	+0.140	−0.226	+0.058	+1.641	+0.627
1886	24	+0.538	+0.342	−0.309	+0.090	+1.694	+0.680
1887	18	+0.552	+0.650	−0.507	+0.092	+2.064	+1.050
1888	13	−0.264	+0.718	−0.305	−0.044	−0.061	−1.075
1889	10	−0.176	+1.170	−0.061	−0.030	+1.475	+0.461
1890	20	+0.104	+0.693	−0.009	+0.017	+1.026	+0.012
1891	22	+1.094	+0.145	−0.383	+0.183	+2.150	+1.136
Weighted Means	162	+0.441	+0.497	−0.244	+0.074	+1.513	+0.499
				Observer R.			
1884	31	−0.032	−0.681	−0.296	−0.005	−0.033	+1.027
1885	27	−0.702	+0.532	−0.520	−0.117	−0.758	+0.302
1886	25	−0.282	+0.775	−0.135	−0.047	−0.702	+0.358
1887	21	−0.526	+0.198	−0.336	−0.088	−0.011	+1.049
1888	10	−0.466	−0.816	−0.182	−0.078	−0.048	+1.012
1889	26	−0.780	−0.155	−0.048	−0.131	−1.522	−0.462
1890	24	−0.814	+0.775	−0.325	−0.136	−1.403	−0.343
1891	30	−0.228	+0.158	−0.467	−0.038	−0.320	+0.740
Weighted Means	194	−0.461	+0.240	−0.302	−0.077	−0.632	+0.428

Year.	No. of Obs.	$(x \cdot \sin \omega)$.	$\delta\omega$.	y.	δa.	Error of Longitude (Tabular *minus* Observed).	Error of Longitude (Tab. − Obsd.) corrected for mean values of x for each observer.
				Observer F.B.			
		″	″	″	s	″	″
1884	33	+0·528	+0·146	−0·250	+0·088	+1·137	+0·270
1885	29	+0·815	+0·072	+0·100	+0·136	+1·801	+0·934
1886	20	+0·412	+0·004	−0·053	+0·069	+1·987	+1·120
1887	19	−0·407	−0·535	−0·267	−0·068	+1·627	+0·760
1888	12	−0·335	+0·203	−0·231	−0·056	+1·924	+1·057
1889	24	−0·312	+0·725	−0·222	−0·052	+1·384	+0·517
1890	11	+1·351	−0·157	+0·322	+0·226	+1·131	+0·264
1891	25	+0·813	+0·769	−0·560	+0·136	+2·127	+1·260
Weighted Means	173	+0·377	+0·197	−0·174	+0·063	+1·632	+0·765

The systematic character of the differences between the errors of the tables in longitude deduced directly from the observations of Messrs. Wickham, Robinson, and Bellamy is sufficiently pronounced to be recognised in the results of a single year. The mean errors of the tables in longitude for the years 1884–1891 are

(23) W. = +1″·513; R. = −0″·632; F.B. = +1″·632;

and the weighted mean is +0″·765.

The corresponding values of the constant, y, are

(24) W. = −0″·244; R. = −0″·302; F.B. = −0″·174.

These values of y agree fairly well with the weighted mean −0″·250, and they show that no very strongly marked personalities exist in the observations of the Sun in N.P.D.

The corresponding values of $\delta\omega$ are

(25) W. = +0″·497; R. = +0″·240; F.B. = +0″·197;

and these corrections to the tabular obliquity are also fairly accordant with the weighted mean +0″·280.

But the values of $(x \sin \omega)$ indicate the existence of well-marked differences in the habits of the observers in taking transits of stars and one, or both, of the limbs of the Sun.

The mean values of $(x \sin \omega)$ for the different observers are

(26) W. = +0″·441; R. = −0″·461; F.B. = +0″·377;

and for x

W. = +1″·108; R. = −1″·157; F.B. = +0″·946;

which show that the R.A. of the Sun as directly found by each observer requires to be corrected for

$$W. = +0^s{\cdot}074\,;\ R. = -0^s{\cdot}077\,;\ F.B. = +0^s{\cdot}063\,;$$

whilst the personal equations for transit observations of stars referred to the mean habit during the period under discussion are

$$W. = +0^s{\cdot}15\,;\ R. = -0^s{\cdot}37\,;\ F.B. = +0^s{\cdot}22.$$

It may be mentioned here that all the transit observations at the Radcliffe Observatory are made by the "eye-and-ear" method. The personal equations for stars are large, but the personal equation of Mr. McClellan, who succeeded Mr. Bellamy in 1892, falls about half-way between W. and R.

The differences in the errors of the solar tables in longitude for the different observers given in (23) are due to differences in personalities in observing transits of stars and of limbs of the Sun. When we apply the corrections, x, found for the three observers to their corresponding errors in longitude, see equation (14), we have for the mean errors of the tables in longitude, or $(-\delta\theta)$, at the epoch 1888·0,

$$(27) \qquad W. = +0''{\cdot}499\,;\ R. = +0''{\cdot}428\,;\ F.B. = +0''{\cdot}765$$

and the weighted mean is $+0''{\cdot}560$.

The extreme difference of the results (27) only amounts to $0''{\cdot}34$, whilst for the results (23) the extreme difference is $2''{\cdot}26$.

The results (27) are certainly within the chance errors of their determination, which include those of the constant $x \sin \omega$ multiplied by 2·3; whilst the results (23) are discordant beyond any possible chance errors of their determination or the effects of the errors of the tables in longitude. The personal corrections in time required by the right ascensions of the Sun for the different observers

$$W. = +0^s{\cdot}074\,;\ R. = -0^s{\cdot}077\,;\ F.B. = +0^s{\cdot}063$$

have been found quite independently of any existing errors of the tables in longitude; and, although liable to sensible chance errors of determination, they must be regarded as approximate determinations of the absolute corrections required by the right ascensions of the Sun found by the three Oxford observers with the R.A. of clock stars in use.

If we apply these corrections to the observed R.A. of the different observers, the "errors of the tables," both in ecliptic polar distance and longitude, will be less dependent on the distribution of the observations during each year among the observers; and we may be able to obtain more accurate values of the constants x', y, and $\delta\omega$ by a rediscussion of the errors of ecliptic polar distance. In this rediscussion the symbols y and $\delta\omega$ will denote the same physical quantities as before, but x' will not

denote the same quantity as x. The equations connecting the x and x' for the different observers are:
For

$$\text{W.}, x = +1''\cdot108 + x'; \quad \text{R.} = -1''\cdot157 + x'; \quad \text{F.B.} = +0''\cdot946 + x'.$$

In this rediscussion the constants x' will be assumed the same for each observer.

The results thus obtained for x', y, and $\delta\omega$ are given in the following table (β), and those found from the system hitherto adopted of neglecting the personalities are given in table (γ).

TABLE (β).

Year.	No. of Obs.	(x'. sin ω.)	$\delta\omega$.	y.	$\delta\alpha$.	Error of Long. (Tabular *minus* Observed).	Error of Long. (Tab.—Obsd.) corrected for mean values of x'.
					s		
1884	87	+0".201	+0".204	−0".187	+0·034	+0".580	+0".594
1885	88	+0·092	+0·198	−0·186	+0·015	+0·632	+0·646
1886	69	+0·128	+0·452	−0·216	+0·022	+0·690	+0·704
1887	58	−0·174	+0·180	−0·440	−0·029	+0·953	+0·967
1888	35	−0·659	+0·122	−0·225	−0·110	+0·253	+0·267
1889	60	−0·551	+0·447	−0·166	−0·092	+0·085	+0·099
1890	55	−0·083	+0·560	−0·045	−0·014	−0·094	−0·080
1891	77	+0·432	+0·318	−0·451	+0·072	+1·021	+1·035
Weighted Means	529 = sum	−0·006	+0·308	−0·242	−0·001	+0·560	+0·574

TABLE (γ).

Year.	No. of Obs.	(x. sin ω.)	$\delta\omega$.	y.	$\delta\alpha$.	Error of Long. (Tabular *minus* Observed).	Error of Long. (Tab.—Obsd.) corrected for mean values of x.
					s		
1884	87	+0".294	+0".260	−0".256	+0·049	+0".799	+0".624
1885	88	+0·233	+0·166	−0·157	+0·039	+0·961	+0·786
1886	69	+0·220	+0·450	−0·190	+0·037	+0·911	+0·736
1887	58	−0·100	+0·077	−0·422	−0·017	+1·169	+0·994
1888	35	−0·511	+0·034	−0·120	−0·086	+0·623	+0·448
1889	60	−0·557	+0·467	−0·224	−0·093	+0·140	−0·035
1890	55	−0·055	+0·463	−0·087	−0·009	−0·013	−0·188
1891	77	+0·509	+0·266	−0·468	+0·085	+1·180	+1·005
Weighted Means	529 = sum	+0·076	+0·280	−0·250	+0·013	+0·765	+0·591

The results of column 7 and not column 8 are usually given as the errors of the tables in longitude in the published results of the Observatories.

The results, Table (β), obtained by this rediscussion are in close agreement, as they should be, with those found by a separation of the observations of the Sun made by the different observers; and they differ but little from those obtained by neglecting the differences between the values of x for the observers and trusting to the chance of a sufficiently uniform distribution of the observations amongst the observers over the year to destroy the effects of personality on the average values of the constants for all the observers.

The errors of Le Verrier's solar tables in longitude, or $-\delta\theta$ after the corrections for the mean values of x or x' have been applied (see equation 14), are as follows:—

Epoch 1888·0.

Table (α).—Weighted mean of separate individual results $= +0''{\cdot}560$.

Table (β).—Rediscussion with personal corrections $= +0''{\cdot}560 + 0''{\cdot}006 \times 2{\cdot}3 = +0''{\cdot}574$.

Table (γ).—Method hitherto adopted, but with correction for x applied $= +0''{\cdot}765 - 0''{\cdot}076 \times 2{\cdot}3 = +0''{\cdot}590$.

The close agreement of the results (γ), after correction for x, with (α) and (β) shows that for the years 1884–1891 the solar observations have been fairly distributed amongst the observers over the different parts of the orbit. If the constants x and y are neglected, the errors $+0''{\cdot}20 + 0''{\cdot}25 \cos\theta$, see equations 14, 24, and 27, are thrown upon the solar tables.

When the method of personal corrections is adopted, it will be necessary from time to time to examine these corrections by a rediscussion of the "errors of ecliptic polar distance" of the tables of the Sun deduced from the observations of the different observers.

This method of applying personal corrections, found independently of the errors $\delta\theta$, to the right ascensions of the Sun appears sound in theory, and advantageous in practice at those observatories where only two or three observers are engaged upon the work, and when the separation of x for each observer from the mean errors of the tables in longitude can, therefore, be practically effected.

There is one point connected with these differences of habit in observing the transits of stars and the limbs of the Sun which appears to deserve notice.

The corrections x which we have found refer strictly to the observations of the Sun in right ascension, and they will not be identical with those required by the adopted R.A. of the clock stars if the observer has different habits of observing the transits of the limbs of the Sun and stars. When, therefore, the epoch corrections are computed as usual from the equation

$$\delta\alpha' = \frac{x''}{15},$$

such personalities of the observer, or observers, are necessarily thrown upon the fundamental right ascensions of the clock stars, and this is true whether all the observations of the Sun are made by one person or by several.

In the case of the three Oxford observers, the epoch-corrections thus computed for each observer are

$$W. = +0^s{\cdot}074\,;\ R. = -0^s{\cdot}077\,;\ F.B. = +0^s{\cdot}063.$$

The weighted mean is $+0^s{\cdot}013$, and this agrees very closely indeed with that which I used—viz. $+0^s{\cdot}014$—in the formation of the "Radcliffe Catalogue of 6,424 Stars for 1890." But this correction involves the effects of the mean personalities of the three observers as well as any constant error of the adopted right ascensions of the clock stars used for the determination of the errors of the clock.

We have no direct means, so far as I know, of deciding whether or no any particular observer has any personalities of the kind under consideration. We cannot, therefore, directly eliminate such effects of personality from our work. But we have a choice of methods. We can accept the mean habit of several observers as probably less affected by such personalities and more stable than the habit of any one observer, or we can select some standard observer and attempt to adopt his habits as free from error or as giving rise only to a constant error in our work. I am strongly of opinion that on fundamental points it is much safer to trust to the mean habit of several good observers than to that of one; in fact, the selected standard observer, practically, will change with age, and it will be exceedingly difficult to connect his past and present habits with those of other observers.

The solar observations discussed in the present paper afford, in my opinion, a rather striking example of the great reliability of means.

The observations at Oxford 1884–1891 were based on the Greenwich clock-star lists. The errors of the tables in longitude given by the separate observers, W., R., and F.B., uncorrected for personalities, differ systematically and very sensibly from each other; but if we take the mean error in longitude found directly from the observations of all the observers combined, both at Oxford and Greenwich, for the errors of the tables in mean longitude we have, 1884–1891:

Oxford	$+0''{\cdot}765$,
Greenwich	$+0''{\cdot}758$.

The two results are therefore practically identical. This is, of course, to some extent a matter of chance; but the errors of the tables given by the Oxford observations would have differed very sensibly from those given by the Greenwich observers had I rejected, underweighted, or corrected Mr. Robinson's observations

simply because his results differed from the observations of Messrs. Wickham and Bellamy. There is no sensible difference in the habits of the three observers W., R., and F.B. in taking transits of the first and second limbs of the Sun. To show that such is the case the corrections to the tabular semidiameter found from the observations of the different observers are given in Table (δ). The mean correction for the time of passage of the semidiameter is $+0^{s}\cdot063$, and this result does not differ by quite a hundredth of a second from the three separate results for the different observers. There are very slight indications of personal differences in the semidiameters in N.P.D.; but these differences are much too small and uncertain to render any attempts at correction necessary or desirable. But on the effects of personalities in the N.P.D. observations see the values of y given in Table (*a*).

Radcliffe Observations, 1884–1891.

Errors of Tabular Semidiameter of the Sun for each Observer.

TABLE (δ).

	R.A.						N.P.D.					
	W.		R.		F.B.		W.		R.		F.B.	
Year.		No. of Obs.		No. of Obs.		No. of Obs.		No. of Obs.		No. of Obs.		No. of Obs.
	s		s		s		″		″		″	
1884	+0·064	25	+0·069	34	+0·063	35	−0·36	26	+0·29	33	+0·49	39
1885	+0·074	30	+0·049	24	+0·067	25	+0·20	31	+0·28	26	+0·23	30
1886	+0·074	22	+0·065	26	+0·072	21	+0·34	22	+0·13	20	+0·29	23
1887	+0·057	18	+0·023	20	+0·080	14	+0·24	17	+0·29	18	+0·15	17
1888	+0·059	10	+0·045	8	+0·065	11	+0·54	11	+0·05	9	+0·53	12
1889	+0·050	10	+0·037	25	+0·076	23	−0·10	10	+0·11	25	+0·19	20
1890	+0·035	19	+0·067	24	+0·041	11	−0·06	16	+0·04	22	+0·33	9
1891	+0·072	22	+0·070	28	+0·086	23	+0·34	22	+0·34	27	+0·73	24
Weighted Means	+0·063	156	+0·056	189	+0·070	163	+0·13	155	+0·21	180	+0·38	174

The existence of well-marked differences in the observations of the transits of the Sun has induced me to try whether the same difference of habit exists in the case of the Moon. On account of the comparatively much larger errors of the Lunar Tables, and the rapidity with which they change, we cannot expect that the application of the corrections

$$W. = +0^{s}\cdot074 \qquad R. = -0^{s}\cdot077 \qquad F.B. = +0^{s}\cdot063$$

to the observed right ascensions will give the same mean errors in longitude for the different observers unless a large number of observations of the Moon, extending over many years, are included in the discussion. But with a large number of observa-

tions the effects of the real errors of the tables should not seriously affect the differences of the errors of the tables thus found for each observer. This test has been applied to the lunar observations made in the years 1884–1891, and the results thus obtained are given in the following Table (ϵ).

Radcliffe Observations of the Moon, 1884–1891.

Mean Errors of the Tables in Longitude for each Observer.

(*Tabular* − *Observed.*)

TABLE (ϵ).

Year.	Observer.	Errors of the Tables in Longitude.	Errors of the Tables in Longitude Corrected for Personal Values of x.	No. of Observations.
		″	″	
1884	W.	−0·15	−1·19	12
	R.	−3·21	−2·13	27
	F. B.	−0·30	−1·18	22
1885	W.	−1·19	−2·23	13
	R.	−3·85	−2·76	22
	F. B.	+0·25	−0·63	22
1886	W.	−1·65	−2·69	17
	R.	−3·49	−2·41	21
	F. B.	−0·30	−1·18	11
1887	W.	−3·17	−4·21	9
	R.	−4·19	−3·11	27
	F. B.	−0·99	−1·87	18
1888	W.	−1·49	−2·53	11
	R.	−3·41	−2·33	19
	F. B.	−1·45	−2·33	14
1889	W.	−2·91	−3·95	18
	R.	−4·56	−3·48	27
	F. B.	−2·11	−3·00	17
1890	W.	−2·21	−3·25	12
	R.	−4·89	−3·81	22
	F. B.	−2·45	−3·33	12
1891	W.	−1·45	−2·49	15
	R.	−4·18	−3·10	32
	F. B.	−1·95	−2·83	18
Weighted Means 1884–1891	W.	−1·79	−2·83	197
	R.	−3·99	−2·91	197
	F. B.	−1·07	−1·95	133

These results are the errors of Hansen's Tables, corrected for δt, as given in the volumes of the *Radcliffe Observations*, and with tabular semidiameters corrected by $-0^{s}\cdot06$.

It will be seen that the application of the personal equations deduced from the observations of the Sun has greatly reduced the differences of the errors of the Lunar Tables deduced from the observations of the Moon by the different observers.

As a further check upon the sensible uniformity of the habits of the observers in taking transits of the limbs of the Sun and Moon I have had the errors of the tables of the Moon in R.A. for both limbs collected for the different observers. The results uncorrected for personalities are given in Table (ζ), and the results corrected for the personalities, found from the observations of the Sun, are given in Table (η).

Mean Errors of the Tables of the Moon in R.A. for each Observer (Tabular – Observed), uncorrected for x.

TABLE (ζ).

Year.	☽1L. W. s	No. of Obs.	☽1L. R. s	No. of Obs.	☽1L. F.B. s	No. of Obs.	☽2L. W. s	No. of Obs.	☽2L. R. s	No. of Obs.	☽2L. F.B. s	No. of Obs.
1884	−0·068	9	−0·250	18	−0·066	14	+0·203	3	−0·142	9	+0·132	6
1885	−0·103	7	−0·293	15	−0·063	12	−0·070	5	−0·181	7	+0·126	10
1886	−0·142	13	−0·248	17	−0·070	5	+0·078	4	−0·040	3	+0·050	5
1887	−0·257	7	−0·326	18	−0·196	11	+0·055	2	−0·189	9	+0·180	6
1888	−0·175	6	−0·263	11	−0·066	9	+0·028	5	−0·175	8	−0·058	5
1889	−0·212	9	−0·383	15	−0·117	10	−0·160	7	−0·205	11	−0·114	7
1890	−0·267	7	−0·346	11	−0·201	9	+0·103	3	−0·324	11	+0·027	3
1891	−0·217	7	−0·337	20	−0·178	9	0·000	8	−0·197	11	−0·046	8
Weighted Means	−0·174	65	−0·305	125	−0·118	79	0·000	37	−0·199	69	+0·040	50

Corrected for Personal Values of x.

TABLE (η).

Year.	☽1L. W. s	No. of Obs.	☽1L. R. s	No. of Obs.	☽1L. F.B. s	No. of Obs.	☽2L. W. s	No. of Obs.	☽2L. R. s	No. of Obs.	☽2L. F.B. s	No. of Obs.
1884	−0·142	9	−0·173	18	−0·129	14	+0·129	3	−0·065	9	+0·069	6
1885	−0·177	7	−0·216	15	−0·126	12	−0·144	5	−0·104	7	+0·063	10
1886	−0·216	13	−0·171	17	−0·133	5	+0·004	4	+0·037	3	−0·013	5
1887	−0·331	7	−0·249	18	−0·259	11	−0·019	2	−0·112	9	+0·117	6
1888	−0·249	6	−0·186	11	−0·129	9	−0·046	5	−0·098	8	−0·121	5
1889	−0·286	9	−0·306	15	−0·180	10	−0·234	7	−0·128	11	−0·177	7
1890	−0·341	7	−0·269	11	−0·264	9	+0·029	3	−0·247	11	−0·036	3
1891	−0·291	7	−0·260	20	−0·241	9	−0·074	8	−0·120	11	−0·109	8
Weighted Means	−0·248	65	−0·228	125	−0·181	79	−0·074	37	−0·122	69	−0·023	50

The errors of the Lunar Tables are so large, and change so rapidly, that a complete elimination of their effects from these results can hardly be expected. But the much closer agreement of the corrected results for the different observers is quite evident.

If we take the means of the results for the two limbs for each observer to eliminate the effects of the tabular semi-diameter, the correction to which is not very accurately determined, we have

$$W. = -0^{s}.161\,;\ R. = -0^{s}.175\,;\ F.B. = -0^{s}.102.$$

These results agree very closely; but they appear to show, like the solar observations—see (27)—that the value of x found from Mr. Bellamy's observations in Ecliptic Polar Distance is rather smaller than the true value.

In the present paper attention has been directed to the existence of very sensible systematic differences in the habits of three skilled observers in taking transits of stars and of limbs of the Sun and Moon. The theory of the effects of such personalities has been discussed, and very approximate determinations of the values of these personalities have been found from a discussion of the solar observations, independently of any errors of the Solar Tables in longitude; and it has been shown that no sensible differences in the habits of the observers exist in taking transits of the two limbs of the Sun. These personal corrections have been shown to be applicable to the case of the Moon as well as of the Sun. The errors of the Solar and Lunar Tables are, by the adoption of these corrections, sensibly freed from the effects of the personalities in the observers; and they differ sensibly from those which are usually accepted as the errors of the tables when the corrections, x, are neglected.

It would appear that a very sensible increase in the accuracy of our determinations of the errors of Solar and Lunar Tables should result from this method of finding the personal corrections, x, and their use as corrections to the observed R.A.

Preliminary Note on a Personal Equation depending on Magnitude affecting the Right Ascensions of the Stars in the Cambridge Zone Catalogue of the Astronomische Gesellschaft, and its determination from Astrographic Catalogue Plates. By Arthur R. Hinks, B.A.

(*Communicated by Sir R. S. Ball.*)

The Cambridge Zone Catalogue was completed by Mr. Graham at the end of 1896. In accordance with the programme of the Gesellschaft the Cambridge zone overlaps the northern Berlin zone (Dr. Becker's) by 20′. There are thus a number of stars common to the two catalogues, and a comparison between their places in the two affords a means of determining any systematic error which is not common to both.

With the assent of the director I undertook to make the comparison as part of my regular work at the Cambridge Observatory, and the results of this and the subsequent work suggested by it form the substance of this note.

The zone +24° 50′ to +25° 10′ is common to the Cambridge and Berlin zones, and 671 stars, mainly within these limits, are found in both catalogues. A table was formed giving the difference (Cambridge − Berlin) of the catalogue right ascensions and declinations of each star. It was immediately evident that the differences in R.A. were small, about $0^s{\cdot}07$ on the average, but were in general positive, and that there was thus a systematic difference between the catalogues. The differences in declination were small, about $0''{\cdot}5$ on an average, and with them we are not concerned in this note. They appeared to be mainly accidental.

The most probable cause of such a discrepancy appeared to be the existence of a personal equation depending on magnitude affecting one or more probably both series of observations. Several of the observatories co-operating in the scheme of the Astronomische Gesellschaft had already investigated this question in reference to their own observations, and determined a magnitude equation of sensible amount. The Cambridge Catalogue is particularly well adapted to furnish evidence of value on this point, since by far the greater part of the R.A. observations were made by one and the same observer, Mr. Graham. The results should, therefore, be homogeneous so far as personal equation is concerned.

Before, however, discussing the differences with reference to personal equation, it is necessary to satisfy ourselves as far as possible that no other causes may have contributed to the observed discrepancy. To do this we must glance at the circumstances under which the observations were made.

The work on the zone catalogue was begun at Cambridge in the summer of 1872. Until the autumn of 1883 the stars were

observed in zones, mostly over three wires, and they were reduced by means of tables prepared for each zone. The stars which then remained unobserved were not sufficiently well distributed to make zone observations desirable. The zone method was therefore dropped, and thenceforward the catalogue stars were observed and reduced in the same manner as the clock stars, except that they were usually taken over five wires instead of seven.

The Berlin observations were all made in zones, and were completed in the four years 1880–1883.

From 1883 January 1 a small and probably quite unimportant change was made in the adopted clock-star list. Up to this date the Astronomische Gesellschaft had published yearly star ephemerides based upon Dr. Auwers' *Fundamental-Catalog*, and the Cambridge R.A.'s depended upon these. After 1882 these ephemerides were discontinued, and at the same time the clock-star list of the *Berliner Jahrbuch* was much enlarged and the star places made to depend upon the *Fundamental-Catalog*. A number of the stars in the latter were, however, omitted from the ephemeris as superfluous or otherwise undesirable as clock stars, and some corrections to the star places which had been published in the *Vierteljahrsschrift der Astronomischen Gesellschaft* were incorporated. From 1883 January 1 the right ascensions of the Cambridge stars are based upon this list.

In order to determine whether the trifling dissimilarity in the circumstances of the Berlin and Cambridge work, and the slight want of homogeneity in the latter, had had any appreciable effect on the results, the observed differences of R.A. (Cambridge – Berlin) were weighted and divided into three groups according to the dates of the individual observations at Cambridge.

Group I. included all stars of which the individual observations were all taken before 1884 January 1, and whose catalogue R.A.'s depend, therefore, almost entirely upon zone observations and reductions and upon the Gesellschaft ephemerides.

Group II. included all stars of which the individual observations were made some before and some after 1884 January 1.

Group III. included all stars of which the individual observations were all made after 1884 January 1. They were neither observed nor reduced by zones, and their R.A.'s depend upon the *Jahrbuch*.

The formula used for weighting the differences was

$$\frac{4mn}{m+n+\frac{1}{3}mn},$$

where m and n are the numbers of observations in the two catalogues. (See the papers by Messrs. Turner & Hollis, *Mem. R.A.S.*, vol. li. p. 53, and by Mr. Stone, *M.N.* 1869, p. 324.) It is to be remarked that this formula is properly applicable only when the probable errors of one observation in the two catalogues

are equal, which is not quite true in the present case. The error thus introduced will be, however, quite inappreciable.

The means for each group were taken for each three hours of R.A., and the results are given in the following table:—

TABLE I.

R.A. h h	I. Mean. s	I. Weight.	II. Mean. s	II. Weight.	III. Mean. s	III. Weight.	Totals. Mean. s	Totals. Weight.
0– 2	+·056	142	+·049	85	+·067	112	+·058	339
3– 5	+·063	148	+·082	77	+·100	229	+·089	434
6– 8	+·033	216	+·045	112	+·082	154	+·051	482
9–11	+·058	161	+·099	48	+·060	49	+·066	258
12–14	+·067	104	+·055	120	+·112	37	+·068	261
15–17	+·053	78	+·048	114	+·040	100	+·047	292
18–20	+·037	288	+·040	194	+·049	39	+·039	521
21–23	+·044	240	+·073	95	+·077	111	+·058	446
Totals ...	+·048	1377	+·056	845	+·078	831		

It is immediately evident from this table that there is a great part of the discrepancy between the two catalogues which cannot be attributed to the above-mentioned slight want of homogeneity in the Cambridge methods. The stars in Group I. were observed on the average four or five years earlier at Cambridge than at Berlin, but at both observatories the method of observation and reduction was the same. The resulting R.A.'s should therefore be strictly comparable. We find, on the contrary, that there is a well-marked discrepancy of about ^{s}·05 even in this first group. It does not seem probable, therefore, that the somewhat larger discrepancy shown by the third group can be due in any great degree to the small change in the method of observation and reduction which, as is mentioned above, took place in the later years of the work at Cambridge. If this change be supposed to have any influence at all, it can be measured only by the difference between the mean residuals in Groups I. and III.—that is, by about ^{s}·03. We have to account in some other way for the balance of the residual. But until we discover the cause of this residual as a whole we cannot be sure that the effect of such cause is the same in all three groups.

It is equally clear, from an inspection of the mean residuals for every three hours of R.A., that no large part of the discrepancy can be attributed to errors in the assumed positions of individual clock stars, such as might arise from erroneous determinations of their proper motion. It is true that there is a fairly well-marked minimum in hours 15–20, and perhaps also in hours 6–8; it is, however, as well marked in the early as in the late years, and can therefore scarcely be accounted for by a progressive error in the places of the clock stars. And the argument of the last paragraph applies here with equal force,

that, until we can account for the existence of the discrepancy as a whole, it is unsafe to assign any definite origin to variations in its amount.

It remains, then, to try whether the original hypothesis—of the existence of a personal equation depending on magnitude or illumination of the field—will account for the observed discrepancy. In the Cambridge meridian circle the arrangement designed to admit of the observation of faint stars over bright wires in a dark field was not successful. It was superseded by mounting a plate of red glass so that it could be lowered in front of the opening in the axis through which the light for the bright field illumination was admitted. The wires then appeared dark but faint in a dull red field. This glass was not used in the observation of clock stars, or in some cases of zone stars bright enough to be seen easily in the bright field. As a rule, stars below $7^{m}\cdot0$ were taken in the red field, and zone stars brighter than this sometimes in the red, sometimes in the bright field.

The magnitudes which have been adopted in this grouping are taken from the Berlin Catalogue. These are, in accordance with the programme of the Astronomische Gesellschaft, independent estimates on Argelander's scale. At Cambridge it was considered inadvisable to attempt more than a check on Argelander's Durchmusterung magnitudes. If a star differed notably from the magnitude there assigned to it the observer's estimate was noted. But in general the catalogue magnitudes are practically Argelander's. In view of the later developments of the work the adoption here of the Berlin magnitudes is to be regretted. It is unlikely, however, that its effect is sensible.

The stars were accordingly divided into four groups, whose limiting magnitudes are shown at the head of the columns of the following table. The means and weights are given as before for every three hours of R.A.

TABLE II.

R.A.	I. −6·9.		II. 7·0−8·0		III. 8·1−8·9		IV. 9·0−	
	Mean.	Weight.	Mean.	Weight.	Mean.	Weight.	Mean.	Weight.
h h	s		s		s		s	
0– 2	−·014	30	+·010	46	+·071	168	+·082	95
3– 5	+·026	27	+·048	25	+·079	218	+·106	184
6– 8	+·001	34	−·001	61	+·065	261	+·062	126
9–11	+·010	10	+·015	40	+·050	94	+·099	114
12–14	+·015	31	+·010	60	+·057	78	+·132	92
15–17	−·032	20	+·025	33	+·038	143	+·084	96
18–20	−·047	12	+·002	84	+·030	290	+·079	135
21–23	+·014	42	+·039	50	+·054	260	+·100	94
Totals...	+·003	206	+·018	399	+·056	1512	+·093	936

There can be no doubt that we have here arrived at the principal cause of the discrepancy between the Cambridge and Berlin Catalogues. The observations are affected by a personal equation depending on magnitude. It remains to determine whether the error is in one or both series.

Immediately after the conclusion of the zone observations for his catalogue, Dr. Becker made a series of experiments on thirteen evenings to evaluate the influence of magnitude on his R.A. observations. By using movable screens of fine wire gauze placed in front of the object-glass he was able to observe at the same transit stars alternately at their natural brightness and with their light diminished by a known amount. He came to the conclusion that, assuming the mean magnitude of the clock stars is $4^{m}\cdot0$, the R.A.'s of the Berlin Catalogue require a correction of $-^{s}\cdot007$ per magnitude – that is, that the fainter stars were observed late. Combining this result with those in Table II. we conclude that in both cases the R.A. observations are affected by a personal equation depending on magnitude, but that the amount of the equation is considerably greater in the Cambridge observations.

The work had just arrived at this stage when I received from Professor Turner, in connection with quite another matter, a table of the differences between the Oxford photographic measures and the Cambridge Catalogue places of twenty-six stars on one of the Astrographic Catalogue plates. It immediately occurred to me that the photographic results afforded the best possible test of the reality of the magnitude equation. For the photographic places are deduced in the following way:—From the assumed coordinates of the centre of the plate and the Cambridge Catalogue places the rectangular coordinates of all the Cambridge stars on the plate are computed, and compared with the actual measures on the plate of those stars. From the differences between the two the constants of the linear expression which corrects for error of centring and scale value, refraction, aberration, &c., are deduced, and the measured coordinates are corrected appropriately. The differences between the computed and the corrected observed coordinates of the known stars should then be merely accidental. It is evident, however, that if this personal equation depending on magnitude exists, the R.A. coordinate of the centre of the plate will be too large by an amount depending on the mean magnitude of the stars from which it is deduced. Hence all the x coordinates, corresponding practically to R.A.'s, which are deduced from the plate will be in error by the amount of the mean personal equation affecting the known stars. But the R.A.'s of brighter stars of the Cambridge Catalogue will be in error by less than this amount, and the fainter stars will be in error by more. When, therefore, we compare the measured and computed coordinates of the stars on the plate we shall expect to find the differences in the x coordinates (Oxford Photographic

—Cambridge Zone Catalogue) positive for stars brighter than the mean, negative for stars fainter.

I grouped the residuals in x coordinates from Prof. Turner's list according to the respective magnitudes of the stars, and it was immediately evident that those for the fainter stars were in general negative. This result was sent to Prof. Turner with a request for more material, and he very kindly placed at my disposal all he had then available, the residuals from seven plates. These were divided according to the magnitudes of the stars into four groups, which correspond exactly to the four groups in Table II., except that the magnitudes are Cambridge instead of Berlin. The quantities are decimals of a réseau interval, five minutes of arc. To reduce them to seconds of R.A. they must be multiplied by 20 sec $\delta = 22{\cdot}3$.

TABLE III.

Mean x residuals from seven plates taken at Oxford for the Astrographic Catalogue.

No. of plate.	Coords. of R.A. h m	Centre. Decl. °	Mean mag. of known stars.	Mean residuals and number of stars from which they were deduced. I. −6·9	II. 7·0−8·0	III. 8·1−8·9	IV. 9·0−
859	0 0	+26	8·9	+·0116 2	+·0063 2	−·0014 4	−·0014 20
888	0 40	+26	8·8	...	+·0019 3	+·0031 8	−·0014 18
929	0 48	+26	8·9	+·0071 1	+·0020 3	+·0039 5	−·0013 26
1045	0 48	+26	8·9	+·0085 1	+·0029 3	+·0047 5	−·0013 26
1046	0 56	+26	8·7	...	−·0004 3	+·0019 9	−·0067 11
866	2 0	+26	8·0	+·0004 4	+·0012 5	−·0044 7	+·0003 5
1049	2 32	+26	8·7	+·0024 1	+·0010 2	+·0010 13	−·0014 12

In general the number of stars on a plate which belong to any one group is so small that it is unsafe to base any conclusions on the value of the mean residual for a particular plate and group. In the reduction all the star places of the Cambridge Catalogue were given equal weight, though of many of the fainter stars—stars which were not included in the original programme of the Astronomische Gesellschaft—there was but a single observation. In these cases the error of the catalogue place may be comparatively large, and the corresponding large residual will in a small group entirely swamp the rest.

The apparently abnormal value for the third group of plate 866 seems, however, to be real. The seven residuals from which the given mean is derived are: $-^{R}{\cdot}0071$, $-^{R}{\cdot}0029$, $^{R}-{\cdot}0057$, $-^{h}{\cdot}0074$, $-^{R}{\cdot}0067$, $-^{R}{\cdot}0002$, $-^{R}{\cdot}0006$. This plate is, however, exceptional, in that the known stars on it are bright, their mean magnitude being 8·0. The residuals for the group of stars whose magnitudes are 8·1 − 8·9 would therefore be much smaller algebraically than usual, and it is evident that we cannot compare the means as they stand on this plate with those on the

other plates, upon which the known stars are much fainter. The value $+^{R}\cdot 0003$ for the last group on this plate is dominated by one large positive residual. Three of the four others are negative.

We have, then, in Table III. for any one magnitude group a number of mean residuals which differ greatly among themselves. A large part of this irregularity is due to accidental errors, since there are on a single plate but few stars belonging to the brighter groups. It is desirable, therefore, to combine the results of a large number of plates in order to get rid of this accidental error. The preceding paragraph, however, shows that it is not legitimate to take the simple mean of a column of the results in Table III., owing to the variation in the mean magnitude of the known stars on different plates. The question then arises, How can these results be combined?

The only systematic error which was to be feared in the photographic measures themselves was one due to personality in bisection. This has been entirely avoided at Oxford by turning the plates through 180° and re-measuring. The adopted measures, which are the means of the two series, will then be free from any such error. These mean measures in each coordinate are corrected by a linear formula, of which the constant term corrects for error of centring of the plate; and into the determination of this constant enter all the systematic errors of the catalogue from which the places of the known stars are taken.

The right ascension of a star in the Cambridge Catalogue may be considered sensibly free from personal equations depending upon velocity and direction of motion in the field, or upon the position of the instrument, since the stars all lie in a zone 5° broad, and the instrument was never reversed. It will involve the difference between the absolute personal equations affecting the observation of the star in question and the mean of those affecting the clock stars taken within an hour or two of it. It will also involve the mean error of the adopted R.A.'s of the clock stars, depending upon personal equations, error of adopted mean equinox, &c.

Let, then, E be the correction to be applied to the observed R.A. of a zone star, owing to absolute personal equation.

E_c the correction for a clock star.

F the mean error of the adopted R.A.'s of the clock stars.

Then for any star in the Cambridge Catalogue

$$\text{Absolute R.A.} = \text{Cambridge R.A} + (\text{E} - \text{mean } \text{E}_c) + \text{F}.$$

And for the same star on the Oxford plates

$$\text{Absolute R.A.} = \text{Oxford R.A.} + \frac{1}{n}\Sigma\{\text{E} - \text{mean } \text{E}_c + \text{F}\}$$

if there are n known stars on the plate.

In general the same clock stars would be used for the whole of the region, 2° square, covered by one plate. Consequently the mean E_c is the same for all stars on the plate, and we have

The residual in the x coordinate, which is practically equal to Oxford R.A.—Cambridge R.A. $= E - \frac{1}{n} \Sigma (E)$.

Now this term $\frac{1}{n} \Sigma (E)$ is the mean of the absolute personal equations for all the stars on the plate, and will vary therefore for different plates. Even if the mean magnitude of the stars on two plates is the same, the value of $\frac{1}{n} \Sigma (E)$ will not in general be the same, unless E can be expressed as a linear function of the magnitude. But it is in any case a constant for the plate $=$ C suppose. If, therefore, the personal equations for two stars are E and E′, and the corresponding residuals R and R′, we have

$$E = R + C$$
$$E' = R' + C,$$

and

$$E - E' = R - R'.$$

We can therefore combine the *differences* between the corresponding quantities in the columns of Table III. without any reference to the magnitudes of the known stars on the plates. This result is perhaps sufficiently obvious from the consideration—which is a summary of the above reasoning—that the individuality of the plate, so far as personal equation is concerned, enters only into the constant which corrects for the error of centring of the plate, and cannot, therefore, affect the difference between two measures on the same plate; for except in the case of a very special distribution with respect to magnitude of the known stars on a plate, the error in the determination of the coefficients of x and y in the linear correction formula which will be produced by the adoption of the slightly erroneous values of the R.A.'s may be considered negligible. It is, however, not quite so obvious that the quantities obtained by subtracting the columns of Table III. are differences of absolute personal equation, and involve neither errors in the R.A.'s of the clock stars nor personal equation in observing them. It seemed worth while, therefore, to retain the detailed consideration of this point which is contained in the preceding paragraphs.

We have in Table III. practically results from only six plates, since 929 and 1045 are duplicates. The mean of the two has been treated as one plate. If, then, we form the differences between the columns of Table III., weight them by the formula used above, and take the means, we have—

Groups.	Mean Residuals. R	s	Weights.
IV.–I.	−·0061	= −·136	17
IV.–II.	−·0039	= −·087	37
IV.–III.	−·0032	= −·071	55

Comparing these with the results deduced from the comparison of the Berlin and Cambridge Catalogues we have—

TABLE IV.

	Comparison of Cambridge and Berlin A Uncorrected Berlin Personal	B Corrected Equation.	Ox'ord Photographic Measures C.
	s	s	s
Stars in Group IV. are observed later than stars in Group I. by	·090	·110	·136
later than stars in Group II. by	·075	·086	·087
and than stars in Group III. by	·037	·042	·071

The second column has been formed on the assumption that the Berlin R.A.'s must be decreased ^{s}·007 per magnitude (see above), and that the stars of Groups I., II., and III. are on an average $2^{m}\cdot8$, $1^{m}\cdot6$, and $0^{m}\cdot6$ respectively brighter than those of Group IV.

The general agreement of these two determinations in columns B and C of the effects of the personal equation must be considered satisfactory, when due allowance is made for the small amount of material upon which the photographic results are based. A considerable disagreement between columns A and C would be no argument against the validity of the photographic method, since the quantities in the third column are the differences of absolute personal equation between the different magnitude groups, and in the first column the differences of relative personal equation—that is, the differences of the values of the quantity "Cambridge–Berlin personal equation."

The third column, on the other hand, should agree with the second, since the Berlin results used in forming it have been corrected by the value of the personal equation, $-^{s}$·007 per magnitude, which was found at Berlin from observations made with wire gauze screens. This method is, however, open to the serious objection that the change in the character of the star's image due to the diffraction of the screen is very likely to have an appreciable influence on the observer's habit. The results of Table IV. seem to show, moreover, that the personal equation function is not linear, at least in the case of the Cambridge observations.

The method used above of dividing the stars into four groups according to their magnitudes was sufficiently exact to show the dependence of the personal equation upon magnitude. When, however, we come to the problem of determining the form of the function of the magnitude which represents the personal equation this method is insufficient, and at present there is not enough material available for an exact investigation. But there is evidence besides that of Table IV. which seems to show that the function is not linear.

It was noticed during the grouping of the residuals for the

formation of Table III. that of those that went into the last group, magnitude 9·0 and fainter, the residuals belonging to the stars marked 9·0 were in general positive, and that the mean of the group was rendered negative only by the somewhat large negative residuals for the fainter stars. They were therefore collected for each tenth of a magnitude from $8^m{\cdot}5$ downwards, neglecting the results from plate 866. The following table gives the number of stars in each group and the mean residual :—

TABLE V.

Mag.	No. of Stars.	Mean Residual.	Mag.	No. of Stars.	Mean Residual.
8·5	6	R + ·0033	9·1	11	R − ·0020
8·6	6	+ ·0016	9·2	13	− ·0105
8·7	5	+ ·0010	9·3	13	− ·0052
8·8	3	− ·0028	9·4	6	− ·0057
8·9	6	+ ·0011	9·5	18	− ·0026
9·0	24	+ ·0049	...	...	...

It appears from this table that the assumed magnitudes of the stars are not very well distributed. Apparently there has been a tendency to mark stars $9^m{\cdot}0$ rather than $8^m{\cdot}7$, $8^m{\cdot}8$, or $8^m{\cdot}9$. This tendency would, however, have made somewhat too large the assumed mean magnitude, $8^m{\cdot}8$, of the stars on the plates under discussion at the same time that it increased the number of stars marked $9^m{\cdot}0$ having a positive residual. It can hardly, then, affect the important indication which this table affords, that the value of the mean residual vanishes, not for stars of the mean magnitude, but for stars sensibly fainter. The meaning of this result is sufficiently obvious—the function of the magnitude which represents the personal equation for that magnitude is not linear. If a curve were drawn having magnitudes as abscissæ, and the corresponding personal equations as ordinates, it would become much steeper for the fainter stars.

It has been convenient so far to consider the personal equation a function of the magnitude—that is, of the logarithm of the brightness of a star. It is quite probable, however, that it can be better represented as an algebraical function of the brightness. The point cannot be settled until there is more material available for discussion.

To sum up :—There is a small systematic difference between the R.A.'s of the Cambridge and Berlin Zone Catalogues, which varies with magnitude, and is probably due to a personal equation depending on magnitude. If we accept as final the results obtained at Berlin with wire gauze screens, faint stars were observed late at both observatories, but the effect was rather more pronounced at Cambridge. This is confirmed on the whole by a discussion of residuals which occur in the reduction of a few of the Oxford Astrographic Catalogue plates, and for a

complete investigation of the question these residuals form the best possible material. When, therefore, the reductions for the Astrographic Catalogue are completed it will be possible to discuss very accurately the personal equations depending on magnitude in the observations for the meridian catalogues upon which it is based.

In conclusion, I must express my thanks to Professor Turner for the results from the Oxford University Observatory which he has kindly placed at my disposal, and I am also indebted to him and to Mr. Newall for much very helpful advice and criticism.

The Observatory, Cambridge:
1897 *April* 8.

An Investigation concerning the Position Error affecting Eye-Estimates of Star Magnitudes. By Alexander W. Roberts.

Measures of star magnitudes according to the method of Argelander, or any of its modifications, are always liable to be seriously vitiated by several disturbing influences. Attention has been directed from time to time to these sources of error by astronomers who have made special study in this branch of astronomical research; not infrequently they have been pointed out in order to throw discredit on the determination of star magnitudes by eye-estimates.

It is evident, however, that the mere existence of error in any series of measurements, of whatever nature, cannot condemn the measurements made, unless it is also certain that the errors cannot be avoided or eliminated. Now with ordinary precautions the chief errors that influence eye-estimates of stellar brightness can be entirely negatived, either by avoiding them or by adopting expedients which render them inoperative.

One of the principal influences modifying almost every observation made by eye-estimates is that arising from the ever-changing relative position of a variable and its surrounding comparison stars. Put generally, the error arises from the tendency, common, apparently, to all observers, to over-estimate the brightness of the lower star or stars in any field. If the amount of error were insignificant, it might be neglected without endangering seriously the substantial accuracy of any determination depending upon light measurements; but the amplitude of error is frequently almost a whole magnitude, an amount much greater than the actual variation of some shorter-period variables. Then in addition to the magnitude of error arising from this source we have its systematic nature. Now it is evident that a subjective systematic variation in the magnitude of any star whose light changes are under consideration will find expression

in definite terms, the derivation of which it will be impossible to assign either to subjective change due to unequal sensitiveness of different parts of the retina, or to actual objective changes in the light of the star itself.

Thus we may have an apparent certain variation in the light of a star that after all is but the result of this tendency to over-estimate the brightness of the lower of two objects. It is pertinent, therefore, to the subject of stellar astronomy to investigate as thoroughly as possible a phenomenon that bears so directly on the accurate determination of star magnitudes.

The error may be avoided by taking observations when the star is in the same hour angle. This is not, however, always possible, and with rapidly varying stars it is out of the question. Then, again, the error may be avoided by the observer keeping his head always in the same position with relation to the stars under examination. For very evident reasons this expedient has been found to be practically unworkable. Another method of overcoming the difficulty will naturally suggest itself to many. The field under examination might always be kept in the same position with respect to the vertical by means of a rotating prism. In this case "position error" (using this term to describe the error now under consideration) would affect the absolute magnitudes of each star, but the excess or defect being always a constant quantity, the variation of the star would in no way be influenced.

None of the foregoing methods yield any data for an investigation as to the amount and nature of "position error." They are, indeed, effective expedients for its elimination, but they afford no means of ascertaining the amount of error eliminated.

I have had it in purpose for some years to adopt only such a mode of observation as would yield simply and readily the amount of error due to subjective causes, and the method that seemed best suited for such a purpose was that in which two observations are always taken—one direct, and the other reverse. This is secured by using for each observation two eye-pieces—one astronomical, and the other terrestrial.

It is evident that whatever stars are over-estimated when using one eye-piece, will be under-estimated to an equal extent when the other eye-piece is used. Thus a mean of the two observations will yield a set of measures entirely freed from position error. But, further, the difference between the two sets of measures (when properly reduced to a common standard) will yield *twice the amount of position error affecting any one of the stars at the time of observation.* Then if complete observations of the same set of stars be made in at least twelve hour angles, we shall have all the data necessary for a full investigation of the relation existing between the varying magnitudes and the changes in position producing the variation.

Instead of utilising all available observations I think it will give definiteness to the investigation to limit the area under

examination to one group of stars. For such an investigation several groups of stars are available, but I think the group that yields itself most readily to the investigation is that surrounding the short period variable, Lac. 5861.

The positions of this variable and its surrounding comparison stars are as follows :—

A.Z.C.	Lac.	R.A. (1875). h m s	Dec. ° ′ ″	Mag.
259	5834	14 3 57·6	−57 43 39	7·61
505	5859	7 48·1	56 42 45	7·26
512	...	7 51·1	57 44 29	7·87
533	5861	8 10·2	57 16 12	Var.
639	5870	9 56·8	58 6 21	7·40
837	5888	14 13 8·0	57 42 58	7·56

It will be evident from the accompanying chart that the configuration of the group (fig. 1) is in every way advantageous

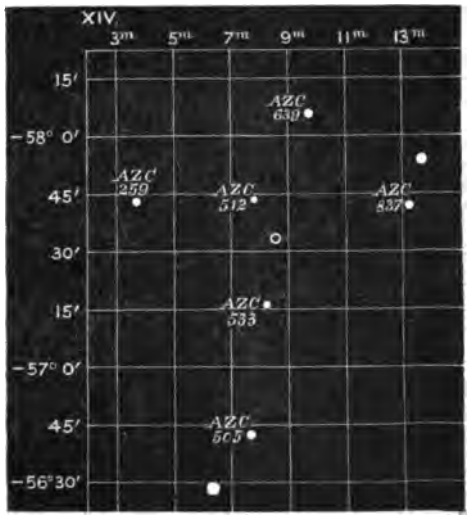


Fig. 1.

to a full investigation. Attention at this point may be called to the position marked O in the chart; this is the centre of the field, and is found in the usual way by triangulating the stars in the system.

The coordinates of O are :—

R.A. $14^h\ 8^m{\cdot}5$

Dec. $-57°\ 33'{\cdot}0$.

The line passing from the zenith through this point will be called the vertical line.

The mode of reducing the estimated magnitudes to standard values bears directly on the question under consideration, and may briefly be described here.

Let

$$M_{(1)} + M_{(2)} + M_{(3)} + M_{(4)} + M_{(5)} = N$$

be the magnitudes of the five comparison stars A.Z.C. 259, 505, 512, 639, 837, as determined by sequences from $6^m{\cdot}8$ at a single observation, N being the sum total of the five magnitudes.

Let M_v be the magnitude of the variable A.Z.C. 533 (Lac. 5861) as determined with relation to the five comparison stars.

From all the observations a mean value of N is found: the average of over 500 values of N gave as this mean value

$$37{\cdot}70.$$

Then to reduce the magnitudes of the five comparison stars to mean standard value, the correction

$$\frac{37{\cdot}70 - N}{5}$$

is applied to each star, making the sum total of the five magnitudes,

$$M_{(1)}, M_{(2)}, M_3, M_{(4)}, M_{(5)},$$

always equal to 37·70.

The same correction is also applied to the variable, which therefore becomes

$$M_v + \frac{37{\cdot}70 - N}{5}.$$

This reduction is rigorously carried out for all observations direct and reverse.

The reduction being completed, the difference between the reverse and direct observations will represent twice the error due to the relative positions of the six stars in the group, the variable and the five comparison stars.

In the accompanying table the differences are taken in groups of one hour, and the parallactic angle of O is given in the same table, as the reduction of the differences will naturally be related in the first instance to this angle.

TABLE I.

Rot. No.	No. of Obs.	Sidereal Time.	Parallactic Angle.*	Reverse—Direct Observations.					
				A.Z.C. 259.	A.Z.C. 525.	A.Z.C. 512.	A.Z.C. 533.	A.Z.C. 639.	A.Z.C. 837.
		h m	° ′	m					
1	4	5 46	44 12	−0·54	+0·54	−0·14	+0·16	−0·44	+0·46
2	4	6 37	54 0	·62	·53	·19	·18	·47	·55
3	5	7 29	63 50	·57	·53	·21	·13	·47	·57
4	16	9 40	89 39	·79	·44	·18	·13	·21	·62
5	26	10 27	100 11	·82	·30	·17	+0·09	−0·05	·65
6	28	11 27	115 46	·83	+0·14	·11	−0·02	+0·04	·77
7	35	12 32	137 52	·71	−0·32	−0·02	·09	·29	·85
8	49	13 29	161 1	·46	·57	+0·03	·22	·57	·65
9	61	14 27	188 42	−0·19	·65	·03	·32	·73	·38
10	55	15 29	216 14	+0·08	·68	·04	·33	·78	+0·11
11	32	16 29	237 39	·39	·73	·10	·23	·68	−0·20
12	37	17 33	255 27	·61	·63	·13	·11	·51	·51
13	40	18 29	268 24	·73	·54	·20	·10	·34	·65
14	42	19 26	280 10	·80	·34	·18	·07	+0·16	·74
15	38	20 24	291 26	·87	−0·06	·13	·04	−0·05	·85
16	20	21 27	303 20	·78	+0·20	·05	−0·00	·11	·93
17	8	22 32	315 48	+0·67	+0·49	+0·02	+0·10	−0·32	−0·93

If the residuals in the preceding table be plotted down, and a curve drawn through the positions, it will be found that all the five curves can be well represented by an expression of the form,

$$\alpha + a \cos (q - M) + \beta \cos (2q - N).$$

From the nature of the error under investigation the first term of the above expression should be sufficient to satisfy the residuals of Table I., but as it is extremely improbable that observations 180° of parallactic angle, apart, will be taken under the same conditions, the second term is retained.

A rigorous least squares solution of the seventeen sets of observations given in Table I. (weighting each set according to the number of observations in the set) yielded the following numerical values for the variation of the position error, depending on q, the parallactic angle at O.

(1) A.Z.C. 259.

$$-0^{m}\cdot04 + 0^{m}\cdot82 \cos (q - 288^{\circ}\ 22') + 0^{m}\cdot08 \cos (2\,q - 270^{\circ}).$$

* The *parallactic angle* is here considered to be the angle formed at O by the lines passing through the zenith and the south pole.

(2) A.Z.C. 505.

$$+0^m{\cdot}04+0^m{\cdot}85\cos(q-27^\circ\,34')+0^m{\cdot}08\cos(2q-357^\circ).$$

(3) A.Z.C. 512.

$$-0^m{\cdot}04+0^m{\cdot}18\cos(q-240^\circ\,50')+0^m{\cdot}06\cos(2q-236^\circ).$$

(4) A.Z.C. 533.

$$-0^m{\cdot}05+0^m{\cdot}22\cos(q-28^\circ\,40')+0^m{\cdot}06\cos(2q-198^\circ).$$

(5) A.Z.C. 639.

$$+0^m{\cdot}05+0^m{\cdot}70\cos(q-200^\circ\,50')+0^m{\cdot}07\cos(2q-97^\circ).$$

(6) A.Z.C. 837.

$$+0^m{\cdot}05+0^m{\cdot}82\cos(q-121^\circ\,47')+0^m{\cdot}09\cos(2q-72^\circ).$$

A comparison between the observed values given in Table I. and the values computed from the preceding expressions is given in the following table.

Rot. No.	A.Z.C. 259. Obs. m	Comp. m	O−C. m	A.Z.C. 505. Obs. m	Comp. m	O−C. m	A.Z.C. 512. Obs. m	Comp. m	O−C. m	A.Z.C. 533. Obs. m	Comp. m	O−C. m	A.Z.C. 639. Obs. m	Comp. m	O−C. m	A.Z.C. 837. Obs. m	Comp. m	O−C. m	Rot. No.
1	−0·54	−0·49	−0·05	+0·54	+0·85	−0·31	−0·14	−0 26	+0 12	+0·16	+0·15	+0·01	−0·44	−0·52	+0·08	+0·46	+0·31	+0·15	1
2	·62	·60	−0 02	·53	·77	−0·24	·19	·25	+0·06	·18	·16	+0·02	·47	·47	+0·00	·55	·44	+0·11	2
3	·57	·70	+0·13	·53	·67	−0·14	·21	·24	+0·03	·13	·15	−0·02	·47	·40	−0·07	·57	·54	+0·03	3
4	·79	·82	+0·03	·44	·43	+0·01	·18	·18	+0·00	·13	·12	+0·01	·21	·25	+0·04	·62	·72	−0·10	4
5	·82	·82	+0·00	·30	+0·22	+0·08	·17	·14	−0·03	+0·09	·08	+0·01	−0·05	−0 09	+0·04	·65	·74	−0·09	5
6	·83	·79	−0·04	+0·14	−0·03	+0·17	·11	·09	−0·02	−0·02	+0·02	−0·04	+0 04	+0 06	−0·02	·77	·76	+0·01	6
7	·71	·67	−0·04	−0·32	·24	−0·08	−0·02	−0·03	+0·01	·09	−0·11	+0·02	·29	·30	−0·01	·85	·74	+0 11	7
8	·46	·49	+0·03	·57	·47	−0·10	+0·03	+0·00	+0·03	·22	·23	+0·01	·57	·54	+0·03	·65	·65	+0·00	8
9	−0·19	−0·21	+0·02	·65	·68	+0 03	·03	·03	+0·00	·32	·32	+0·00	·73	·75	−0·02	·38	·43	−0·05	9
10	+0·08	+0·12	−0·04	·68	·77	+0·09	·04	·07	−0·03	·33	·30	−0·03	·78	·79	−0·01	+0·11	+0·01	+0·10	10
11	·39	·39	+0·00	·73	·72	−0·01	·10	·11	−0·01	·23	·24	+0·01	·68	·68	+0·00	−0·20	−0·23	+0·03	11
12	·61	·60	+0·01	·63	·59	−0·04	·13	·14	−0·01	·11	·16	+0·05	·51	·49	+0·02	·51	·50	−0·01	12
13	·73	·72	+0·01	·54	·45	−0·09	·20	·15	+0·05	·10	·10	+0·00	·34	·33	+0·01	·65	·67	+0·02	13
14	·80	·79	+0·01	·34	·28	−0·04	·18	·14	+0·04	·07	·06	−0·01	+0·16	+0·16	+0·00	·74	·77	+0·03	14
15	·87	·83	+0·04	−0·06	−0·10	+0 04	·13	·13	+0·00	·04	−0·02	−0·02	−0·05	−0·10	+0·05	·85	·84	−0·01	15
16	·78	·83	−0·05	+0·20	+0·10	+0·10	·05	·10	−0·05	−0·00	+0·01	−0·01	·11	·26	+0·15	·93	·87	−0·06	16
17	+0·67	+0·76	−0·09	+0·49	+0·31	+0·18	+0·02	+0·05	−0·03	+0·10	+0 04	+0 06	−0·32	−0·41	+0·09	−0·93	−0·84	−0·09	17

So far we have considered the values of the errors, the terms expressing their amount and variation, as depending upon the parallactic angle of point O, the central point of the group of six stars. We now arrive at an important transference of argument.

The line passing from the zenith through O we have agreed to call the vertical line. Let, for brevity, the angle formed at O by this vertical line and a line joining O with any one of the five stars be called the position angle. Does the position error reach a maximum (or a minimum) for all stars in the group now under consideration at the same position angle?

It is possible to solve this question graphically, but in a first investigation it is preferable to proceed otherwise.

Let O be the origin of coordinates, and let O_1 be another point to which the measurements of position angle and parallactic angle are referred. Then taking

α and β coordinates of O_1;
α_1 and β_1 coordinates of star;
κ parallactic angle at O when position error is at a maximum;
θ constant position angle when position error is at a maximum;

each maximum of position error (obtained from Table I.) will yield equations of the form

$$(\beta_1 - \kappa\alpha_1)\,\theta + \kappa\,(\theta\alpha + \beta) + (\alpha - \theta\beta) = (\kappa\beta_1 + \alpha_1).$$

It is unnecessary to burden the present paper with the numerical steps leading to the following results:

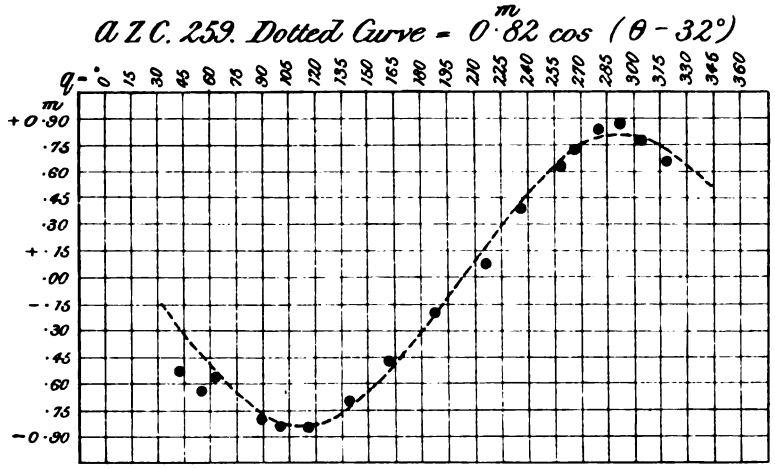
$$\alpha = +1''{\cdot}5$$
$$\beta = -4''{\cdot}3$$
$$\theta = 32°.$$

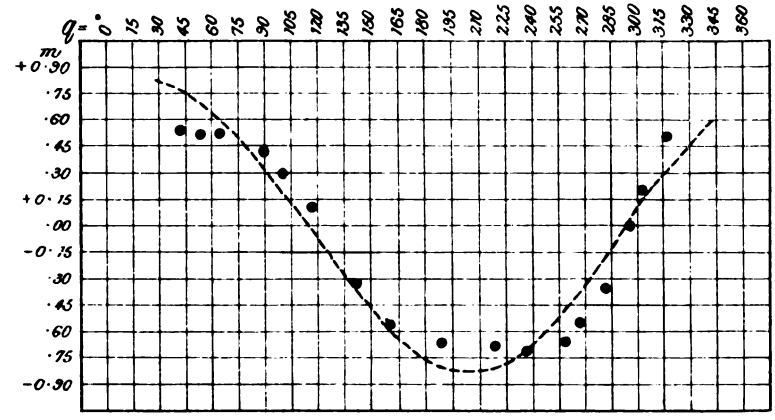
That the equation should yield as a mean point of reference a position only *four and a half minutes of arc* distant from the central point of the field is very remarkable when we consider the character of the investigation. Theoretically I am convinced that the two points O and O_1 coincide, but uncorrected sources of error—as, for example, a slight change in the position of the head when eye-pieces of different lengths are used—combine to produce the slight non-agreement of the two positions.

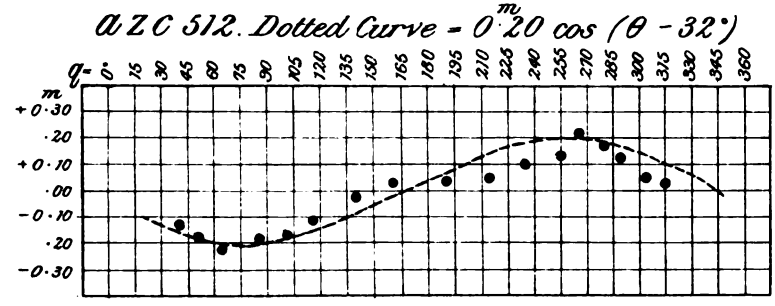
Taking, therefore, as our mean point of reference a position

R.A. $14^h\ 8^m{\cdot}7$
Dec. $-57°\ 37'{\cdot}3'$,

we find that the position errors affecting the magnitudes of the six stars under consideration reach their maximum when the position angle at O is 32°. Or, to put this statement more generally, with


a Z C. 259. Dotted Curve = 0m·82 cos (θ - 32°)
q = ° 0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
m
+0·90
·75
·60
·45
·30
+·15
·00
-·15
·30
·45
·60
·75
-0·90


a Z C. 505. Dotted Curve = 0m·83 cos (θ - 32°)
q = ° 0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
m
+0·90
·75
·60
·45
·30
+0·15
·00
-0·15
·30
·45
·60
·75
-0·90


a Z C 512. Dotted Curve = 0m·20 cos (θ - 32°)
q = ° 0 15 30 45 60 75 90 105 120 135 150 165 180 195 210 225 240 255 270 285 300 315 330 345 360
m
+0·30
·20
+0·10
·00
-0·10
·20
-0·30

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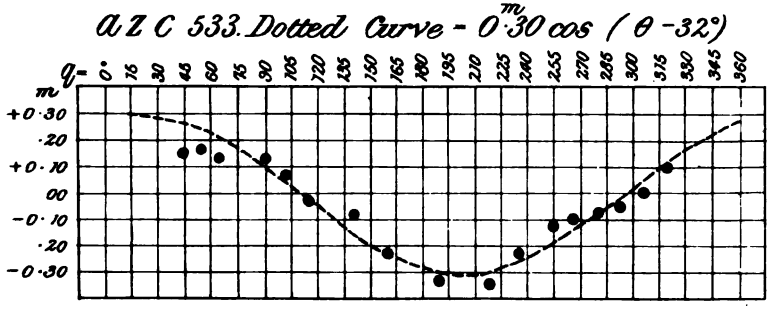

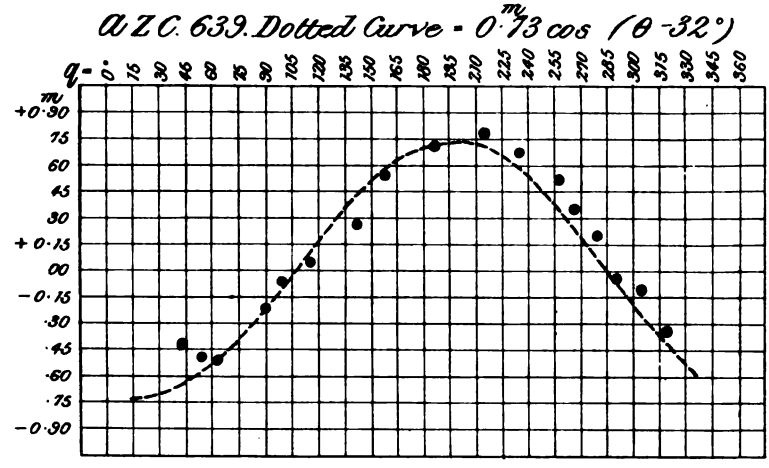

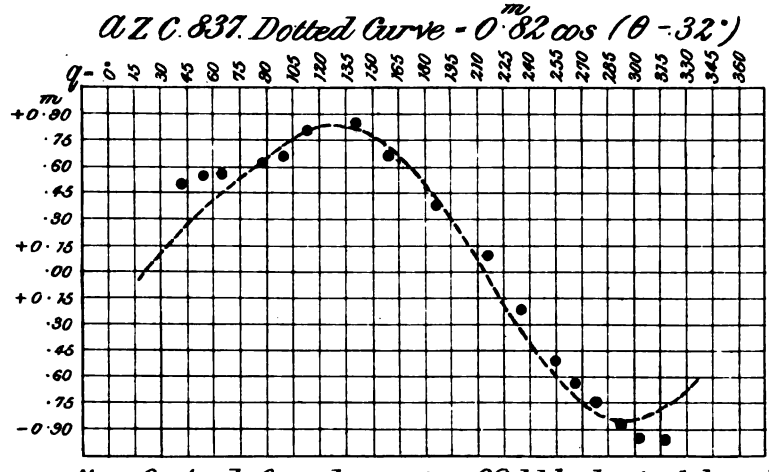

NOTE: θ = Angle formed at centre of field by the star & the nadir.

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any system of stars whose magnitudes are determined visually each star will reach an apparent maximum brightness when the angle subtended by a line drawn from the star to the centre of the field and the vertical line at this point is 32°.

How close a general expression for all the six stars meets the observed differences between reverse and direct observation may be evidenced by graphical illustrations.

The dotted curves (Plates 12 and 13) are computed from the general formula

$$r \cos (\theta - 32°).$$

I am unable to obtain a general expression for r, but it would seem that the further from the centre O the star is, the greater will the coefficient r be. The following table gives the relation :

	Star.	Distance of Star from O.	Observed Values of r.
		′	m
1	A.Z.C. 505	55·1	0 83
2	259	38·3	0 82
3	837	36 6	0·82
4	639	30·8	0 73
5	533	21·5	0·30
6	512	9·6	0·20

The disturbing effects of position error have been commented upon by Safarik (*Ast. Nach.* Band 101, page 24).

It will be seen that the relation existing between the distance of a star from the centre of the field and the amount of error which influences comparative eye-estimates of its brightness is by no means an intimate one ; indeed, we can readily understand circumstances—as, for example, twenty stars in a line—where the relation would naturally break down.

The foregoing investigation has been confined to the group of stars surrounding L. 5861 ; but whatever group be considered, as far as Lovedale observations are concerned, the general results are the same.

(1) The error due to relative position is systematic in its nature.

(2) It reaches its maximum effect when the position angle of the star with relation to the vertical at the centre of the field is 32°.

(3) It affects all magnitudes equally.

These results are absolute as far as my personality is concerned ; whether they hold good for other observers I cannot say. It must not be forgotten, however, that the error has been commented upon at some length by Safarik (*Ast. Nach.* Band 101, p. 24); by Pickering (*Harvard Annals*, vol. xiv. part 1, p. 42); and by Chandler (*Astronomical Journal*, No. 374, p. 107). The two latter astronomers have also proved in the papers referred to the systematic nature of the error. I may be permitted also to say

that Dr. Gould, when corresponding with me some years ago on the matter, informed me that the phenomenon was frequently an anxiety to the Cordoba observers. It is not unreasonable, therefore, to conclude that the error, in at least its general characteristics, influences all eye-estimates of star magnitudes by the method sequences. That there are possibilities, therefore, of grave misleading in discussing observations, in the securing of which no steps have been taken, either through want of care or want of knowledge, to eliminate so important an error, is surely beyond reasonable doubt. Indeed, it is certain that every result based on uncorrected observations is more or less in error.

Whether some of the secondary terms that appear so often in the computed elements of variable stars have their origin in this source of error I cannot say; only it is possible for position error to give rise to such secondary terms when left uncorrected. It is unnecessary to dwell upon the connection existing between this tendency and the exceedingly long lists of suspected variables which now and again find a lodging place in astronomical literature.

The assumption all through this paper, as well as in the papers of Safarik, Pickering, Chandler, and Barnard, is that the error has its source in the eye of the observer. I have convinced myself that this is so by a very simple expedient. The telescope I use is a small 1-inch theodolite. To make sure that the error was not due to the nature or adjustments of the instrument, I rotated the small telescope in its Ys, thus taking the observations with the object glass in all positions. I also used a variety of eye-pieces. Further, when the head was rotated through a certain angle, the same changes in the relative magnitudes of the stars seemed to take place as would have been observed had the stars moved through an equal hour angle.

The error also operates in cases when no optical aid is required.

Proper Motion of the Southern Short Period Variables L Carinæ and K Pavonis. By Alexander W. Roberts.

The following proper motions of *L Carinæ* and *K Pavonis* have been determined solely from observations made at the Cape Observatory. The measures available are the positions given in the General Catalogues for 1840, 1850, 1860, 1880, and the meridian results of 1887, 1888, 1889, 1890, 1891.

The mean places are reduced to 1900·0, using Newcomb's precession constants (*Astron. Constants*, p. 196), and the mean latitude of the Cape Observatory is held to be

$$-33^\circ\ 56'\ 3''.52.$$

Whenever possible Chandler's corrections for latitude variation have been applied, and the various catalogues have been differentially compared.

L Carinæ.

No.	Epoch.	Taken from.	R.A.	Red.	R.A. (1900).	Dec.	Red.	Dec. (1900).	No. of Obs.	Weight
			h m s	m s		° ′ ″	′ ″			
1	1840	Cat. 1840	9 40 51·16	+1 38·99	9 42 30·15	−61 46 18″·11	−16 30″·60	−62 2 48·71	6–9	2
2	1850	Cat. 1850	41 7·74	1 22·48	30·22	49 2·49	13 46·05	48·54	1–3	1
3	1860	Cat. 1860	41 23·96	1 5·98	29·94	51 46·82	11 0·90	47 72	4–4	1
4	1880	Cat. 1880	41 57·07	32·99	30·06	57 17·46	5 30·65	48·11	3–3	1
5	1890	Mer. Result, 1887–91	42 13·34	16·49	29·83	60 2·42	2 45 85	48·27	12–12	3

A discussion of the above reduced places yields the following :—

R.A. (1900) $9^h\ 42^m\ 29^s·795$. P.M. $= -0^s·006$. Dec. $-62°\ 2'\ 48''·09$. P.M. $= +0''·007$.

K Pavonis.

No.	Epoch.	Taken from.	R.A.	Red.	R.A. (1900).	Dec.	Red.	Dec. (1900).	No. of Obs.	Weight.
			h m s	m s		° ′ ″	′ ″			
1	1840	Cat. 1840	18 40 25·12	+6 13·34	18 46 38·46	...	...	...	5–0	2
2	1850	Cat. 1850	41 27·59	5 11·02	38·61	−67 24 42·58	+ 3 11·07	−67 21 31·51	2–2	1
3	1860	Cat. 1860	42 29·59	4 8 73	38·32	24 7·03	2 35·19	31·84	3–3	1
4	1880	Cat. 1880	44 34·09	2 4·27	38·35	22 50·75	1 18·73	32·02	3–3	1
5	1890	Mer. Result, 1887–91	45 36·22	1 2·11	38·33	22 11 99	39·88	32·11	10–10	3

A discussion of the above places yields the following :—

R.A. (1900) $18^h\ 46^m\ 38^s·303$. P.M. $-0^s·003$. Dec. $-67°\ 21'\ 32''·26$. P.M. $-0''·013$.

An Improvement in Winding Equatorial Clocks.

By A. F. Lindemann.

All equatorial clocks are, as far as I am aware, disturbed during winding; but the disturbance is usually hidden by the momentum of the heavy governor. My intention being to detect and correct all driving errors, I constructed an exceedingly light governor, weighing about ¼ oz., and rotating 540 times a minute, the clock being corrected every second by a main pendulum clock. With this arrangement the winding error was most conspicuous, until the new winding was introduced, with the result that a star set to the vertical line of the micrometer and observed with a power of 214 showed absolutely no movement during the most irregular starting, winding, or stopping. The construction of new winding is as follows (Plates 14 and 15, figs. 1, 2 and 3):

I took barrel out of clock (an old one by Cook) and inserted in its place a double V-grooved cast iron sheave (1 and 2) and fixed it to the axle C by a steel screw and by a pin resting against one spoke of the main driving wheel D. Exactly under the axle C I placed the winding axle E, held in position on one side by a screw and washer, on the other by a ratchet-wheel R and ratchet r and a double V-grooved cast-iron sheave 1_1 and 2_1, of the same dimensions as 1 and 2, and carrying on the prolongation of E the winding crank d. Ratchet-wheel and sheave are soldered to E. Fixed to the iron clock support G is the fork H, which carries at the outer end the axle I, upon which the ⌣-grooved loose sheaves a b and a_1 b_1 are placed, secured on both ends by washers and screw heads. Under this fork and just in front of clock support G are fixed by means of a plate and axle the ⌣-grooved guiding rollers c and c_1. An endless clock string, with long splice of 3 feet and about $\frac{3}{16}$-inch thick, carries the weight P and counter weight p as seen in fig. 3, and starting say at β, passing on c and the front of 1 returns to top of a, crossing over to 2, whence it returns over top of b down to sheave r^1, carrying counter weight p, rises on the other side to sheave b_1, passing on and under 2_1, from there crossing over to and under a_1 and over to and under 1_1, from which it passes on to c_1, descending to sheave R (to which is attached the large driving-weight P), and returns from there to β. The action is obvious, the weight P is always with $\frac{P}{2}-\frac{p}{2}$ on driving wheel D. During winding the same is the case, and consequently there is no change in the clock's rate. When winding, all that happens is that the string with P is pulled up by sheave 1_1 and 2_1, the weight p descending the same amount. The ratchet prevents the turning back of axle E with its sheaves, and the whole winding is done by friction. I rejected the chain, which would have been simpler,

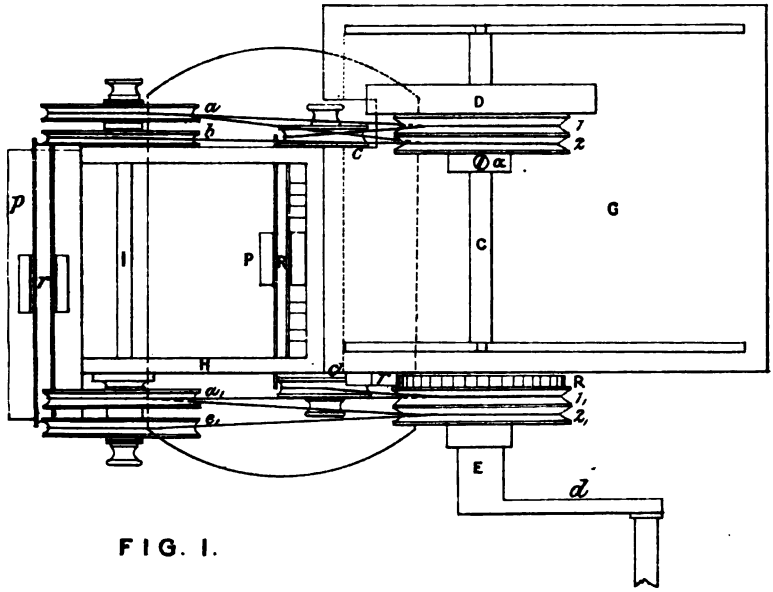
a
b
c
D
1
2
α
G
C
p
I
P
R
H
a1
e1
R
1,
2,
E
d

FIG. 1.

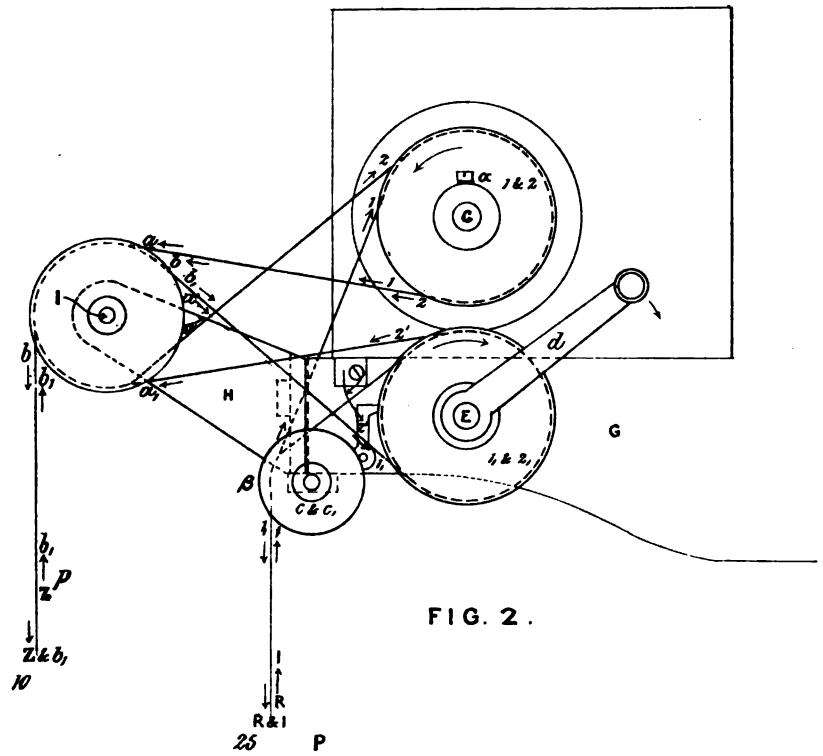
2
α
1 & 2
C
1
a
b
b1
a1
I
H
2'
d
E
G
1, & 2,
β
C & C1
b1
p
Z & b1
10
R
R & I
25
P

FIG. 2.

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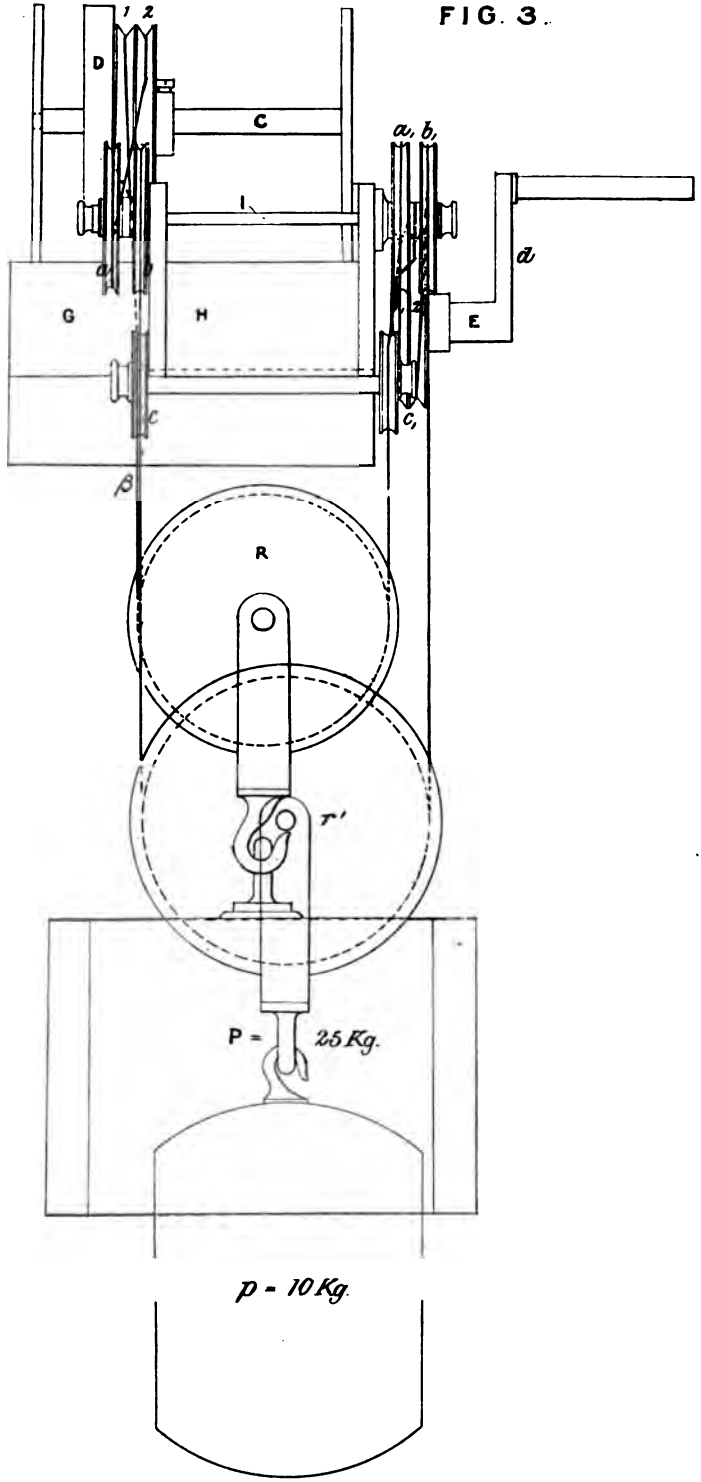
FIG. 3.



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on account of the possibility of uneven working, and fearing that each link might show, which is here avoided. The position of the pulleys a b and a_1 b_1 have been so calculated that they give the greatest amount of frictional angle upon 1 and 2 and 1_1 and 2_1. The friction was primarily calculated and proved a perfect success. The weight p can be lifted without the string slipping. The position of the various sheaves to one another is also most important, the string having to pass itself several times on each side without touching. Cast-iron was chosen, having a great frictional resistance. Naturally in a new clock the arrangement could be made much more compact. This method of winding, the idea of which is old and well known, is only new in so far as it acts without a chain and entirely by friction.

This winding has been in constant use during the last eight months in my observatory with perfect success.

Sidmouth Observatory:
1897 *April* 8.

Observations of Minor Planet (8) *Flora at Windsor, N.S. Wales.* By John Tebbutt.

The accompanying observations of *Flora* have been made with the 8-inch equatorial and filar micrometer and in a bright field. The micrometer differences have been corrected for refraction and a small error in the perpendicularity of the micrometer threads. The quantities $p\Delta$ are based on an equatorial parallax of the sun=8″·85.

(8) *Flora.*

Date.	Windsor Mean Time.	Planet−Star. Δ R.A.	Δ N.P.D.	No. of Comps.	Planet's App. R.A.	Log. $p\Delta$	Planet's App. N.P.D.	Log. $p\Delta$.	Reductions to App. Place R.A.	N.P.D.	Comp. Star.
1895.	h m s	m s	′ ″		h m s		° ′ ″		s	″	
Dec. 1	10 53 10	+2 56·46	+ 7 19·7	12	4 41 52·98	9·154*n*	75 41 2·2	0·811	+5·17	−16·8	1
1	11 4 19	+1 6·86	+ 1 47·6	8	4 41 52·13	9·074*n*	75 41 1·3	0·812	+5·17	−16·6	2
4	10 27 46	−0 24·15	+ 1 6·8	19	4 38 32·11	9·216*n*	75 34 49·5	0·810	+5·21	−16·6	1
4	10 27 46	−2 13·17	...	19	4 38 32·14	9·216*n*	...	...	+5·21	...	2
5	10 38 42	+0 14·01	+ 9 47·4	15	4 37 24·85	9·115*n*	75 32 32·5	0·813	+5·22	−16·8	3
5	10 38 42	−1 31·43	− 1 12·6	15	4 37 24·84	9·115*n*	75 32 30·1	0·813	+5·22	−16·6	1
8	10 18 7	+6 6·81	+ 2 52·1	7	4 34 8·64	9·153*n*	75 25 2·2	0·813	+5·24	−17·6	4
8	10 18 7	−3 2·08	+ 2 17·5	7	4 34 8·79	9·153*n*	75 25 2·8	0·813	+5·25	−16·6	3
9	10 45 19	+5 1·23	+ 0 4·7	5	4 33 3·06	8·860*n*	75 22 14·8	0·817	+5·24	−17·6	4
9	10 45 19	−4 7·60	− 0 30·4	5	4 33 3·28	8·860*n*	75 22 14·9	0·817	+5·26	−16·6	3
18	9 17 7	+0 5·34	+18 10·8	10	4 24 23·35	9·225*n*	74 53 15·7	0·814	+5·32	−17·8	5
18	9 17 7	−0 24·87	...	10	4 24 23·31	9·225*n*	...	...	+5·32	...	6
22	10 19 55	+0 39·91	+ 0 40·8	10	4 21 10·36	8·041	74 37 27·9	0·823	+5·32	−18·1	7

Date. 1896.	Windsor Mean Time. h m s	Planet−Star. Δ R.A. m s	Δ N.P.D. ′ ″	No. of Comps.	Planet's App. R.A. h m s	Log. $p\Delta$	Planet's App. N.P.D. ° ′ ″	Log. $p\Delta$.	Reductions to App. Place R.A. s	N.P.D. ″	Comp. Star.
Dec. 22	10 19 55	−3 7·68	+ 2 23·1	10	4 21 10·35	8·041	74 37 28·2	0·823	+5·34	−17·6	5
22	10 19 55	−3 37·86	+ 5 41·9	10	4 21 10·34	8·041	74 37 28·8	0·823	+5·34	−17·6	6
23	9 39 34	−3 49·27	− 1 38·3	10	4 20 28·76	8·836*n*	74 33 26·8	0·822	+5·34	−17·6	5
23	9 39 34	−4 19·40	+ 1 40·0	10	4 20 28·81	8·836*n*	74 33 26·9	0·822	+5·35	−17·6	6
23	10 29 13	−0 3·18	− 3 29·6	10	4 20 27·28	8·624	74 33 17·6	0·823	+5·33	−18·0	7
24	9 31 45	−0 42·29	− 7 34·0	15	4 19 48·17	8·879*n*	74 29 13·2	0·823	+5·33	−18·0	7

Mean Places of the Stars of Comparison for 1896·0.

Star.	R.A. h m s	N.P.D. ° ′ ″	Authorities.
1	4 38 51·05	75 33 59·3	Glasgow 1870, 1149; Madras 1882, 159; Yarnall, 2065.
2	4 40 40·10	75 39 30·3	Equatorial Comps. with No. 1.
3	4 37 5·62	75 23 1·9	Glasgow 1870, 1141; Madras 1882, 157; Glasgow 1890, 409.
4	4 27 56·59	75 22 27·7	Radcliffe 1860, 519; Brussels 1865, 1749; Glasgow 1870, 1099; Greenwich 1880, 727.
5	4 24 12·69	74 35 22·7	Brussels 1865, 1728; Glasgow 1870, 1083; Greenwich 1880, 717; Glasgow 1890, 389.
6	4 24 42·86	74 32 4·5	Brussels 1865, 1731; Greenwich 1872, 423; Greenwich 1880, 719; Glasgow 1890, 391; Cincinnati 1890, 491.
7	4 20 25·13	74 37 5·2	Radcliffe 1845, 1230; Brussels 1865, 1703; Greenwich 1872, 415.

Windsor, N. S. Wales:
1897 *February* 18.

Observations of Comets 1896 *III.* (*Swift*) *and* 1896 *IV.* (*Sperra*), *at the Radcliffe Observatory, Oxford.*

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100.

Comet Swift.

Date. 1896.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Compa.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. $(\rho \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log. $(q \times \Delta)$.	Ref.
	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Apr. 20	8 57 45	10 50 28	R.	−0 16·65	−1 43·0	9	3 34 39·99	+0·68	9·593	61 46 1·8	12·1	0·840	(*a*)
28	8 44 15	11 8 28	R.	+1 29·05	+0 30·0	3	3 10 50·00	+0·79	9·6762	42 6 35·0	11·0	0·8211	(*b*)
29	9 43 35	12 11 54	C.	+1 15·50	−6 46·5	8	3 6 4·86	+0·64	9·5923	40 0 54·0	12·2	0·8739	(*c*)
May 1	10 40 18	13 16 39	W.	−3 52·73	+0 50·5	3	2 55 52·93	+0·41	9·4130	36 18 2·4	12·8	0·9082	(*d*)
1	10 40 18	13 16 39	W.	−3 58·98	+0 45·5	3	2 55 52·96	+0·41	9·4130	36 18 4·9	12·8	0·9082	(*e*)
2	10 5 49	12 46 1	R.	−1 14·39	−4 17·9	9	2 50 33·05	+0·52	9·5205	34 41 44·6	12·1	0·8912	(*f*)
4	10 44 48	13 33 0	R.	−1 50·45	+6 54·4	6	2 38 43·74	+0·29	9·2934	31 43 0·5	12·2	0·9084	(*g*)
9	10 11 45	13 19 34	R.	+0 17·80	+0 23·8	11	2 6 13·31	+0·23	9·2238	26 8 25·9	10·8	0·8952	(*h*)
11	10 37 23	13 53 9	R.	+2 53·80	−0 46·0	8	1 52 7·50	0·00	...	24 27 54·6	10·4	0·8946	(*i*)
12	9 42 52	13 2 26	R.	+0 30·88	−0 51·1	6	1 45 16·81	+0·22	9·2255	23 45 49·9	10·0	0·8868	(*j*)
14	10 53 1	14 20 40	W.	−4 3·35	−1 50·7	5	1 30 33·04	−0·26	9·3167	22 27 8·0	9·5	0·8796	(*k*)
15	11 8 46	14 40 24	W.	−3 21·89	+2 0·7	6	1 23 15·10	−0·40	9·5096	21 53 9·2	9·1	0·8675	(*l*)
29	11 32 51	15 59 45	W.	+1 34·39	−0 1·8	7	23 43 30·74	−1·10	0·0337	17 41 7·3	4·5	0·6415	(*m*)
June 15	11 ...	...	R.	...	...	...	21 52 ...	...	...	17 40 ...	...	...	(*n*)

Comet Sperra.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Compa.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. ($p \times \Delta$).	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log ($q \times \Delta$).	Ref.
1896.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Sept. 9	10 8 2	21 20 47	W.	−0 41·99	+4 59·4	3	14 9 52·48	+0·36	9·7832	34 57 (42·)	3·2	0·7261	(*o*)
15	11 54 2	23 30 44	R.	−0 11·40	+1 19·5	13	14 51 44·46	+0·29	9·6749	36 24 3·5	4·2	0·8398	(*p*)

Observers' Remarks.

(*a*) Coma nearly round, 2′ in diameter with a condensation. Very low altitude; bright moonlight and some haze.
(*b*) Coma nearly circular; can be traced over a diameter of 3′ Nucleus diffused, about 10″ or 15″ diameter.
(*d*), (*e*), (*f*) Part of the object-glass covered by roof during these observations.
(*g*) Sky hazy. At the close of the observations nearly half of the object-glass was cut off by the roof.
(*h*) Coma 3′. Condensation small. Sky very clear. (*i*) Coma 3′. Condensation generally diffused.
(*k*) Comet is a large, diffused mass. Observations are not very satisfactory. (*l*) A momentary glimpse of a nucleus obtained.
(*m*) Comet a hazy, faint patch, with apparently a tail projecting at an angle of 300° from the north point. Difficult observations.
(*n*) Comet only very occasionally discernible. No observation could be secured; nothing but the roughest estimate possible.
(*o*) The sky has been too thick for anything more than rough work. The comet is a diffused nebulous mass, though I once suspected a nucleus. (*p*) Comet is a faint haze of about 2′ diameter, with a feeble condensation, occasionally invisible.

Assumed Places of the Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	3 34 56·54	+0·10	61 47 53·7	−9·0	Romberg 830
(*b*)	3 9 21·32	−0·37	42 6 14·5	−9·6	Mean of Bonn. A.G. 2730 and Greenwich Observations, 1891, 1893.
(*c*)	3 4 49·82	-0·46	40 7 49·8	−9·3	Bonn. A.G. 2667.
(*d*)	2 59 46·29	−0·63	36 17 20·9	−9·0	Cambridge (Harvard) A.G. 1379.
(*e*)	2 59 52·57	−0·63	36 17 28·4	−9·0	Cambridge (Harvard) A.G. 1381.
(*f*)	2 51 48·17	−0·73	34 46 10·9	−8·4	Radcliffe Transit-Circle Observations, 1896, Dec. 11, 15.
(*g*)	2 40 35·14	−0·95	31 36 13·6	−7·5	Helsingfors-Gotha A.G. 2515.
(*h*)	2 5 56·95	−1·44	26 8 6·2	−4·1	Radcliffe Transit-Circle Observation, 1896, Nov. 6.
(*i*)	1 49 15·31	−1·61	24 28 43·0	−2·4	Barclay Equatorial comparisons with Christiania A.G. 330 and 340.
(*j*)	1 44 47·60	−1·67	23 46 42·9	−1·9	Radcliffe Transit-Circle Observation, 1896, Nov. 6.
(*k*)	1 34 38·13	−1·74	22 28 59·3	−0·7	*Berliner Jahrbuch*, 1896.
(*l*)	1 26 38·81	−1·82	21 51 8·5	+0·1	Christiania A.G. 292.
(*m*)	23 41 57·47	−1·12	17 41 0·4	+8·7	Radcliffe Transit-Circle Observation, 1896, Oct. 31, Nov. 4.
(*o*)	14 10 33·52	+0·95	34 52 38·8	+3·8	Helsingfors-Gotha A.G. 7884.
(*p*)	14 51 55·02	+0·84	36 22 41·6	+2·4	Barclay Equatorial comparisons with Cambridge (Harvard) A.G. 4615, 4636.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson; C., Mr. E. E. McClellan.

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, No. 3349 (*Comet Swift*), and No. 3378 (*Comet Sperra*). For April 20 (*Comet Swift*), the value of log Δ has been inferred from that of April 22.

Radcliffe Observatory, Oxford: 1897 *April* 8.

Erratum in "Nautical Almanac," 1897.

(*Communicated by the Superintendent of the "Nautical Almanac."*)

Nautical Almanac 1897, page 464.

Reappearance of σ *Sagittarii* on August 9. The corrected numbers are :—

Sidereal time.	Mean time.	Angle from vertex.
h m	h m	°
15 47	6 33	220.

Errata in "Monthly Notices."

Vol. lvi. page 168, line 20, *for* Mean 40·013
read „ 40·133

Vol. lvii. page 380, equation (4), *for* $y = \frac{1}{(x^2+s^2)^{\frac{1}{2}}} = \frac{m}{\lambda^2}$

read $y = \frac{1}{(x^2+s^2)^{\frac{1}{2}}} = \frac{1}{\lambda^2}$.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. MAY 14, 1897. No. 7

Sir R. S. BALL, M.A., LL.D., F.R.S., President, in the Chair.

Arthur W. Clayden, M.A., F.G.S., St. John's, Polsloe Road, Exeter; and
Herbert Lovis Noel Noel-Cox, 2 Edinburgh Mansions, Victoria Street, S.W.,

were balloted for and duly elected Fellows of the Society.

Seventy-eight presents were announced as having been received since the last meeting, including, amongst others:—

E. S. Holden, Mountain Observatories, presented by the Author; J. A. C. Oudemans, Triangulation von Java, Abtheilung V., presented by the Netherlands Government; J. Milne and W. K. Burton, The Great Earthquake in Japan, presented by Professor Milne; Lick Observatory Atlas of the Moon, plates 2–5, presented by the Observatory; Harvard College Observatory, photographs taken with the Bruce telescope, presented by the Observatory; Photograph of *Jupiter* by Warren De la Rue, presented by Mr. G. F. Pollock; Lantern slides of the Sun-spots of May 1897, presented by Mr. Newbegin.

On the Various Forms of Personal Equation in Meridian Transits of Stars. By Truman Henry Safford.

The first and historically the most important form of personal equation is that discovered by Bessel in the use of the eye and ear method.

In Bessel's Memoir we find the examples of large personal equations which are most frequently quoted; and to illustrate some of the points I will repeat them. Bessel anticipated Argelander $1^s{\cdot}22$ by eye and ear, and also anticipated W. Struve by $0^s{\cdot}8$. This last value held good strictly for the year 1821, and at that time it was indirectly obtained through Walbeck; and a closer agreement of Bessel and Struve, B.-S. $= -0^s{\cdot}044$, is sometimes quoted. It was found in 1814; and the evidence for it is slight, one transit of *α Lyræ* by Struve and one each of *α Andromedæ* and *γ Pegasi* observed by Bessel. It is not unfair to suspect that the apparent change in Struve's personal equation relatively to Bessel from $0^s{\cdot}04$ in 1814 to $0^s{\cdot}8$ in 1821 was due to irregularity of clock rate on 1814 October 21, more than to a change in the personal equation of either astronomer.[1] *Fomalhaut*, observed by Bessel and Struve 1820 November 13, gave Bessel-Struve $= -0^s{\cdot}68$, but the observation was passed over as too near the horizon of Konigsberg, where the star's altitude was $4°1$-2; yet it agrees well enough with later determinations of Bessel and Struve's personal equation.

Bessel and Argelander inferred from their unprecedented difference of $1^s{\cdot}22$ that Bessel anticipated the true time of transits, while Argelander fell behind it. Bessel, when he used a half-seconds timepiece, observed $0^s{\cdot}5$ later than with the sidereal clock; hence his anticipation with the latter was more than $0^s{\cdot}5$; and we risk but little in considering Bessel's difference of $0^s{\cdot}8$ from W. Struve was mainly due to himself and not to Struve. I believe astronomers in general would agree with this opinion. In 1843 and 1844 Struve was compared with all the observers who took part in the chronometric expeditions of those years, between Pulkova, Greenwich, and Altona, and from these comparisons we find that he agrees within a few hundredths of a second with the general average, including O. Struve, who was the standard observer for the expedition of 1844, and was also nearly an average observer. The comparisons with Bessel give rise to the suspicion that an average of eye and ear observations, giving each observer equal weight, might perhaps be seriously in error.

If we take the equations Bessel-Struve $= -0^s{\cdot}8$, Bessel-Argelander $= -1^s{\cdot}2$, we find enough residual error in the mean result of the observers on almost any theory to leave the conclusion as to the true average observer somewhat doubtful.

[1] The clock's daily rate as used was $5^s{\cdot}92$.

The subject has since 1885 been thoroughly followed up at Greenwich by the combination of the eye and ear and chronographic methods,* and the various older examples of large personal equation which are upon record ; for instance

Maskelyne-Kinnebrook	$1795 = -0^{s}\cdot 8$
Main-Rogerson	$1853 = -0^{s}\cdot 7$
Main-Lucas	$1871, 1872 = -0^{s}\cdot 76$

are worth mentioning in connection with the material accumulated since 1885, chiefly to show that absolute personal errors of considerable magnitude, $0^{s}\cdot 5$ or more, are to be found in either direction, and not solely as anticipations.

Observers of Argelander's type who set down transits by eye and ear $0^{s}\cdot 4$ too late are not often found ; and yet that an error of more than $0^{s}\cdot 3$ must exist in the case of some observers is plain ; so that the fact that either Bessel or Argelander observed transits more than $0^{s}\cdot 6$ too early or too late does not seem as difficult to comprehend as it did many years ago. Mr. Main, for example, was a transit observer of Argelander's type, as was the luckless Kinnebrook in 1795 ; and Maskelyne anticipated three assistants—Dymond, Bayley, and Hitchens—by $0^{s}\cdot 27$, $0^{s}\cdot 18$, and $0^{s}\cdot 14$ respectively ; and if the average $0^{s}\cdot 20$ of these three quantities is taken as an indication, he was much like most modern observers in his manner of noting transits.

In order to put the data of the later Greenwich introductions into a shape for farther discussion, I have brought together the quantities $e'-e$ for the twenty observers who have taken part in the eye and ear transits since 1885, when the practice of observing time-stars by this method was resumed after its disuse about 1859. Of the twenty observers eight are assistants and twelve computers.

By e' I denote the amount by which each observer anticipated by eye and ear the standard chronographic transits of the Royal Observatory ; by e I denote the similar amount by which he anticipated the standard transits by chronographic registration on his own part. Hence $e'-e$ (for the standard observer $e=0$) is the amount by which each observer when he uses the eye and ear method anticipates the standard chronographic transits ; and on reading over the Introductions to the Greenwich Observations we find that for the standard observers e', and for the others $e'-e$, is persistently positive for the whole period from 1885 to 1893 inclusive. For A. D., who served as standard observer till 1890 inclusive, and for eye and ear in 1891, we find the mean of seven values of $e'=+0^{s}\cdot 123$, and for L., standard observer in the two years 1892 and 1893, we find $e'=+0^{s}\cdot 19$ and $+0^{s}\cdot 20$ respectively. But as L. was one of the principal observers for the whole nine

* The earlier discussions at Greenwich refer to the eye and ear method, or the chronographic method used separately but not together.

years, we can readily set down the amounts $e'-e$ by which he anticipated his own chronographic transits for all these years.

For example, in 1885 e' for L. is $+0^s\cdot08$ and $e+0^s\cdot02$; hence in that year L. anticipated by eye and ear his own chronographic transits by $0^s\cdot06$. The sum of the nine values of $e'-e$ is $1^s\cdot27$ and the mean $0^s\cdot141$, hence L.'s mean anticipation of his own chronographic transits is slightly more than that of A. D., the former standard observer.

It would be unsafe to base any generalisation upon the work of two observers only, however skilful and experienced. For the period 1885–1893 there were in service three other astronomers who took a large share in the transit circle observations for nearly all the years, and we find the mean value of $e'-e$ for them to be as follows :—For H. T. $+0^s\cdot030$, seven years, or including a single observation of 1893 with half the weight of a year,

$+0^s\cdot052$ $7\frac{1}{2}$ years.

For T,

$+0^s\cdot033$ 6 years.

The case of one observer, H., has been stated, so far as his chronographic transits are concerned, in *The Observatory* for May 1896.

The mean $e'-e$ for him for the nine years is $+0^s\cdot511$.

Three other assistants took part in the eye and ear observations in 1892 and 1893. The values of $e'-e$ for them are respectively,

A. C. 1892 $e'-e=+0\cdot20$

A. C. 1893 $e'-e=+0\cdot10$

B. 1892 $e'-e=+0\cdot07$

B. 1893 $e'-e=-0\cdot01$

T. H. 1893 $e'-e=+0\cdot22$

For the twelve computers tested from time to time between 1889 and 1893 we find a single one (and he is the junior computer tested in 1893 only) for whom the mean value of $e'-e$ is negative, and this for him represents one determination of e' only. For him $e'-e=0\cdot03$, considerably less than its probable error. Considering all the separate years' results, $e'-e$ for computers as units, we find of the nineteen such results the sum to be $1^s\cdot66$, and their average $0^s\cdot087$. This average would be modified by assignment of varying weights, but cannot be rendered negative.

The outcome of the investigation into the comparative personal equation by the two methods indicates that in the great majority of cases skilled eye and ear observers anticipate their own chronographic transits by amounts in general not far from $0^s\cdot1$. But the observers previously mentioned (like Argelander), who fell behind the true time of transit as much as about $0^s\cdot4$,

require attention at this point. These observers, so far as Greenwich is concerned, seem to be the following :—Kinnebrook 1795, Henry and Main (who nearly agreed with each other) in 1839 and some following years, and W. Ellis in the two or three years which just preceded the introduction in 1854 of the chronograph.

At any rate, the large majority of the Greenwich observers for a century have been men of the "anticipatory" type, if I may so call those who set down eye and ear transits too early as compared with their own chronographic registration or with average observers.

This represents, according to the best evidence I can gather, the following two principles :—

First, that the eye and ear method gives transits of time-stars which by different observers may be set down either too early or too late, but on the average of a number of skilled observers will be nearly correct, and the chronographic method, on the other hand, results in "observed" times of transit which are, on the average, too late by about $0^s{\cdot}1$ or more.

The eye and ear method and its results were discussed by Bessel in his classical memoirs reprinted in Engelmann's collection of the *Abhandlungen*, vol. iii. Argelander, as appears from the *Bonn Observations*, vol. vi. p. 11, accepted Bessel's theory, that Bessel "proceeded from hearing to seeing," while Argelander, to use his own words, "first saw and then heard." The questioned was tested in 1861 by the psychologist Wundt by simple experiments with a heavy pendulum, and he found that observers were, in fact, of the two types ; some of them mentally fixed the place of the moving object too far ahead in its course, and others not far enough.

With the star's images the same is doubtless the case, and the observer's habit of fixing the place mentally at the clock-beat is thus rendered measurable as a psychological phenomenon. Wundt and others have tested also the "simple reaction to a sense impression," and have found out how long it takes an observer to register an impression on any of his senses by using in the registry chronographs or chronoscopes imitated from the astronomical apparatus. It is found that in general the time occupied is from one-tenth to two-tenths of a second, and it is also found that there are two methods of registering, the "muscular" and the "sensorial," and that the "sensorial," in which the observer waits till he is sure of the sense impression, generally occupies $0^s{\cdot}1$ or more longer than the other in which the observer's attention is concentrated upon performing the act of registration. This, too, is confirmed by the astronomical experience of L. and H. (*The Observatory* for May 1896), as well as of Dr. Battermann, who employs the slower method in very precise observations of transits of faint stars.

The conclusions of this paper so far may be thus stated. The experience of observers since 1795 shows that most eye and ear

observers anticipate the true time of transits, at least if the average observer is taken as the standard.

The Greenwich experiments since 1885 indicate that the great majority when they use the eye and ear method almost without exception anticipate the time of their own chronographic transits; that the average chronographic observer registers transits after the time of their occurrence by an amount not greatly different from that which is required to register an impression on the senses; that the difference between the sensorial and muscular methods of "reaction" is confirmed by the experience of L. and H., for ten years at Greenwich.

A question which Bessel left not wholly answered, viz.: "Whether his observations of polar and equatorial stars were homogeneous," has lately assumed some importance; but I must defer till another occasion the computations which I have made, and which show that the Greenwich right ascensions of polar stars since 1889, observed by a new method, are in close accordance with the Berlin *Jahrbuch*, which has been taken as a standard in this respect by a good many observers and has much weight.

The differences between the right ascensions of standard polar stars as derived from the absolute observations, successive double culminations observed by various astronomers, have often attracted enough attention to be mentioned, but have been usually treated as a matter of no great importance. Thus, for instance, Preuss obtained a greater right ascension of *Polaris* than W. Struve did, but the difference $0^s.84$ was possibly due to other causes.

In the arrangements for the Pulkova fundamental catalogue of 1845 this point was carefully attended to by Struve and his assistants; *Polaris* and other polar stars were observed by the individual astronomers with the following results in right ascension for 1845·0.

			h	m	s
For *Polaris*:					
Schweizer	511	observations	1	3	35·74
Fuss	29	,,			34·71
Lindhagen	65	,,			35·22
Wagner	91	,,			35·36
For *H Cephei* 51:					
Schweizer	11	,,	6	25	59·66
Lindhagen	7	,,			59·22
Wagner	28	,,			59·28
For δ *Ursæ Minoris*:					
Schweizer	170	,,	18	22	19·75
Fuss	23	,,			19·45
Lindhagen	17	,,			19·72
Wagner	55	,,			19·56

It will be seen that Schweizer, who observed time-stars very nearly as W. Struve did, and was in that respect very nearly an average observer, assigned larger right ascensions to all three stars than Wagner, while his difference in the same direction from Fuss, who, however, did not observe *H Cephei* 51, was also considerable. We have for *Polaris*, Schweizer-Fuss = $1^s{\cdot}03$, or for δ *Ursæ Minoris*, Schweizer-Fuss = $0^s{\cdot}30$ or $0''{\cdot}27$, reduced to the equator.

(From a paper by Mr. Sokoloff on the movement of the pole as determined by transit observations, in *Mélanges Mathématiques et Astronomiques*, vol. viii. p. 799.)

Similar differences to those between the Pulkova observers about 1845 are indicated among those of 1880 to 1887.

The following are the corrections of the assumed right ascensions of the three polars, *Polaris*, *H Cephei* 51, and δ *Ursæ Minoris*, as observed since 1880 by three observers employing both the eye and ear method and chronographic registration.

(1) Observations by eye and ear :

	Polaris. s	H Cephei 51. s	δ Ursæ Minoris. s
Wagner	−0·12	−0·33	−0·22
Wittram	−0·24	−0·33	−0·21
Harzer	−0·76	−0·61	−0·51

(2) Registered observations :

Wagner	+0·45	+0·10	+0·11
Wittram	−0·39	−0·28	−0·13
Harzer	−0·68	−0·58	−0·41

The vol. i. lately published of the *Annals of the Strassburg Observatory* affords indications of similar differences in the observations of *Polaris* chronographically registered.

The observers were Professor Schur, acting director, and Messrs. Wislicenus, Stechert, Kaufmann, and Dr. Leitzmann. The observations, like those for the Pulkova fundamental catalogues, were referred to the meridian by the help of marks with long focus lenses, the construction attributed to Rittenhouse, introduced at Pulkova by W. Struve. Hence the corrections to the tabular right ascension are based upon double culminations. These corrections denoted by χ are given by Professor Becker as follows :—

	s		s
χ for Schur	−0·58	mean error	±0·21
„ Wislicenus	−0·54	„ „	±0·13
„ „	−0·68	„ „	±0·12
„ Kaufmann	+0·36	„ „	±0·10
„ „	−0·02	„ „	±0·46
„ Stechert	+0·98	„ „	±0·30
„ Leitzmann	+0·65	„ „	±0.36

The two groups of Dr. Wislicenus's observations are separated in the *Annals* because of an interchange of object-glass and eye-piece which might produce a slight difference through alteration of the field illumination. But the difference of the two quantities $-0^s.54$ and $-0^s.68$ is $0^s.14$; less than its mean error $\sqrt{(0^s.13)^2+(0^s.12)^2}$ or $\pm 0^s.18$, so that we can combine the two groups into one result, $-0^s.62$, and we thus see that Dr. Wislicenus observes *Polaris* nearly uniformly with Professor Schur, and decidedly earlier than either Kaufmann, Stechert, or Leitzmann. His difference from Dr. Stechert is $1^s.60$, about five times its mean error, and from Dr. Leitzmann $1^s.27$, with a mean error of not quite a third of the amount.

It will now be seen that a "polar equation," as I may call it, is indicated for the Pulkova observers of 1845 and for their successors since 1880, and also for the Strassburg astronomers of 1883–1888.

But without some process which shall pretty thoroughly eliminate these differences no definite standard can easily be fixed; or, in other words, no standard catalogue of polar right ascensions is practicable, and the need of such a catalogue is apparent. The Greenwich method of observing transits of *Polaris* and the other azimuth stars is not known to be liable to any special personal equation, except the trifling difference between the registration by the two hands.

Of course the clock corrections are obtained by the ordinary methods, and as these produce an average error for time-stars amounting only to about a tenth of a second, we can see that its influence on the right ascension of *Polaris* and other close stars will be trifling. Moreover, the "muscular" method of registration, Professor Newcomb's Method A, is preferable for ordinary time-stars.

It is possible that the delay of the sensorial method, Method B, according to Newcomb, is different for polar and for equatorial stars, and it is not only desirable to investigate the "polar equation" for the standard azimuth stars, but for others of less declination, by both methods, Bradley's and the chronographic.

In Professors Helmert and Albrecht's work on the longitudes of the Prussian Geodetic Institute we find that the Repsold Transit Micrometer, which acts in an analogous manner to the "Greenwich Method," but in a wider range of declination, does good service, and reduces both ordinary personal equations and those referring to polar stars to a far less amount than previous experience indicates.

In attempting to fit a series of transit observations to a standard catalogue, the Pulkova astronomers have adopted a method which indicates the polar equations pretty clearly, and also shows how to eliminate it to a large extent. This process is most clearly set forth in Dr. Romberg's excellent catalogue of 5634 stars for 1875.

Romberg found in using the standard catalogue prepared by Vice-Director Wagner that his own tendency was to observe by eye and ear slow moving stars later by $0^s{\cdot}025$ than Wagner, when for Wagner the mean results of his two methods, eye and ear and chronographic was taken. Romberg's observations at Pulkova began in 1877. Some years earlier, about 1870–1877, he had observed the fundamental stars of Wagner's list at Berlin, and his observations have been reduced by Dr. Marcuse.

The conclusion as to polar equation which I derive from Dr. Marcuse's work is that, at Berlin also, Romberg observed the polar stars later than the standard, the amount being about $0^s{\cdot}019$, not quite so much as at Pulkova.

To eliminate this polar equation from the Pulkova secondary catalogues requires systematic corrections, and the process becomes a little intricate.

It is conceivable that in practice astronomers will be compelled to resort to the Repsold Micrometer for transits of stars more than 5° from the pole, or to photography.

At any rate, the extension of the "Greenwich Method" to greater polar distances is desirable if practicable. Meanwhile nothing is lost by following for the present the best modern practice in ordinary observations of transits.

There are six stars within 5° of the north pole whose right ascensions are regularly observed at Greenwich by the new method, and their co-ordinates are given in the Berlin *Jahrbuch* from Auwers's compilation and based upon the standard of Wagner's observations about 1865.

These six stars are:—1. *Cephei* 43=2 *Ursæ Minoris*; 2. *Polaris*; 3. Groombridge 750; 4. *Cephei* 51; 5. δ *Ursæ Minoris*; 6. λ *Ursæ Minoris*. Besides these there are six others which are also regularly observed in the same way, viz.:—

1. Groombridge 1119.
2. Bradley 1672.
3. Groombridge 2283.
4. Groombridge 3548.
5. Cephei 32=Bradley 2993.
6. Cephei 39=Bradley 3147.

Of the second list of six, No. 1, No. 3, and No. 4 are not in Bradley's catalogue, but all have been abundantly observed since 1814 by W. Struve and other astronomers, so that their proper motions can be accurately determined without applying doubtful systematic corrections to Piazzi or Groombridge, and the best standard polar catalogue for immediate use which I can suggest would be obtained from the Greenwich right ascensions 1889–1893, brought forward with proper motions obtained from the mass of existing reduced observations taken before 1889.

In the use of such a catalogue the observers should compare themselves with its standard by the process indicated in Romberg's

catalogue of 5634 stars; that is, by determining polar deviations (Bessel's n) from close stars above and below pole and nearly at the same hours; for instance, *H Cephei* 51 and *δ Ursæ Minoris*.

My own attempts to determine my "polar equation" by similar comparisons with the *Jahrbuch* standard are given in the *Williams College Catalogue of North Polar Stars*. I found that in the years 1882–1888 I observed by eye and ear slow moving stars relatively about $0^s{\cdot}006$ later than the standard. By chronograph I observed about $0^s{\cdot}010$ or $0^s{\cdot}012$ later than the same standard. These quantities were so small that it was difficult to be certain of them, partly because of the small number of *Jahrbuch* stars available.

The difficulty of discriminating between Professor Smyth's 'instrumental swerving' and personal slowness with the polar stars could have been mitigated by the employment of a more extensive list of close polars, but this was impracticable, for the very stars were among those of such a list I wished to determine, and they were not to be mixed with the determining stars, and so the new Greenwich stars, Groombridge 1119, and the others were set down as observed only when their right ascensions were based upon instrumental corrections determined from Pulkova (*Jahrbuch*) stars. In other words, I did not employ Pond's method of fixing these particular zero points, but contented myself with adding $0^s{\cdot}006$ to a value of n derived from an upper culmination, and subtracting that amount from an n derived from a lower culmination, or, in the cases when that was practicable, taking the mean of the two values of n, when of course the $+0^s{\cdot}006$ and the $-0^s{\cdot}006$ would cancel each other.

The Pulkova astronomers in 1893 examined their "polar equations" by eye and ear comparison again with the same standard of Wagner, and one of them, Mr. Ditshénko, has published a paper (*Melanges Mathématiques et Astronomiques*, vol. vii., pp. 543–553) entitled "L'équation personnelle dans les observations des passages des étoiles polaires." He finds that, nearly as in 1877–1884, Romberg observed polar stars later than the standard by the amount $0^s{\cdot}026$. But three other observers, Morine, Seraphimoff, and Ditshénko himself, observed them earlier, namely, $0^s{\cdot}042$, $0^s{\cdot}015$, and $0^s{\cdot}025$ respectively, and the corresponding corrections are applied to the respective values of n, thus rendering them all homogeneous, but leaving right ascensions reduced by their aid still subject to the observed polar equation.

The observations of secondary right ascensions can be made more homogeneous by additional observations of secondary polars in various declinations by both the eye and ear, and the chronographic method, using as primary polar right ascensions those of Greenwich 1889–1893, and by comparing the results for azimuth or polar deviation from stars above and below pole, so as to apply the Pulkova correction to n, and then put on record the observer's peculiarity in that respect. The stars not in the

Greenwich list of twelve will in that case be affected with the observer's polar equation as the application of the Pulkova correction will eliminate the influence of their equation upon the polar deviations, but not on the final right ascension of the secondary stars so determined; for example, Romberg's Pulkova values of n were thus reduced to agreement with Wagner's standard, but not his determined right ascensions. These exhibit a tendency similar to that of his polar deviation; that is, he observed stars beyond the zenith of Pulkova or Berlin, respectively, later than the standard.

The light equation or *Helligkeits Gleichung* has been investigated by various astronomers and with very varying results.

It is found that by the chronograph observers register the transits of faint stars later than they do those of the brighter stars used for clock correction. The reason of this seems to be a psychological one; a faint impression on the senses is reacted to, according to Wundt and others, later than a stronger one, while by eye and ear a star plainly visible is observed at its transit more nearly in a uniform manner with the brighter ones. Argelander's experience is this: by eye and ear he noted the transits of very faint stars $0^s{\cdot}48$ *earlier* than he did those of stars distinctly visible in his illuminated field. This he suspected, and Professor Auwers has confirmed his suspicion, and even over-confirmed it, for Argelander suspected his variations would be $0^s{\cdot}2$ or $0^s{\cdot}3$, and he correctly, it seems, attributed it to a reversal of his usual mental process of "seeing first and then hearing." The stars to which the usual habit applied were those of 8·7 mag. or brighter; those for which the reversal took place fainter ones, down to 9·7 mag., and observed by taking very special precautions, such as keeping the room dark and writing the times on a sheet of paper under a heavy black framework so that the eye was kept as nearly at rest as possible.

Another form of personal equation (discovered by Dr. Gill) is that caused by opposite direction of motion to that which is familiar. It is very sensible in eye and ear work, and seems there to be due to the observer's somewhat imperfect fractioning of the seconds. This was apparently first noted by Professor Benjamin Peirce and is mentioned in *Chauvenet's Spherical and Practical Astronomy*. This form of equation has been pretty thoroughly tested by the Greenwich observers since 1885 and found trifling for polar stars and still less important for time-stars chronographically registered. The experiments for time-stars are summarised in Professor Turner's paper in the *Monthly Notices*, vol. xlviii. p. 14.

This form of personal equation in chronographic observations of time-stars seems to be indicated by the differences which Professor Küstner and Mr. R. H. Tucker find between stars observed north and those observed south of the zenith. The former are delayed in registration by $0^s{\cdot}02$ or $0^s{\cdot}03$ as compared with the latter.

The personal equations depending on magnitude can be best and most easily studied by observing relative right ascensions of stars in loose clusters which have been micrometrically measured either heliometrically or from their photographs. Examples of such clusters are the *Pleiades*, *Praesepe* and the cluster in *Coma Berenices* lately measured by Dr. Chase with the Yale heliometer. *Praesepe* has been especially well studied by Professor Schur, now Gauss's successor at Göttingen.

It will be seen from what precedes that in the first place the general theory of Bessel as to personal equation is confirmed, and that the same is true with regard to Wundt's explanation of the eye and ear process. Moreover, the eye and ear method is shown to give results capable of employment as nearly accurate on the average. And Wundt's comparison of chronographic registration with the psychological experiments on "simple reaction" is also shown to be justified by the fact that the time required for chronographic registration by the "muscular" method is about the same as that taken up by the shortened or rapid reactions obtained by the same method.

Astronomers need to pursue the subject into more detail, especially in the line of transit observations of stars in loose clusters, comparing them with micrometrical measurements. And there should also be more inquiry into the laws of that portion of the subject which I have called "polar equation," an inquiry which is greatly facilitated by the introduction at Greenwich of the new manner of galvanic registration of the transits of standard stars employed to determine instrumental azimuths.

In his *Grundzüge der physiologischen Psychologie* (3rd. edition : Leipzig, 1887), Professor Wundt ascribes the early experiments, which he describes as "Complicationsversuche," to the impulse of Bessel's discovery of personal equation, and his later "Reactionsversuche" to the experiments made to eliminate personal equations in longitude operations. Thus we see that the riddles which Bessel brought forward, but did not completely solve, have given rise to, and have been greatly helped towards, a more complete solution by the rise of a new branch of science—experimental psychology—which is now pursued in many of the most prominent universities of the world as a new department of study, and it is now possible to combine in a certain degree the study of the human mind with that of the physical universe, and thus to contribute towards the restoration of the unity of philosophical study.

The Spectrum of β Lyræ, as observed at Stonyhurst College Observatory in 1895. By the Rev. Walter Sidgreaves, S.J.

The collection of photographic spectra of *β Lyræ*, obtained with the light-power of the Perry memorial objective, consists of over 100 plates. The series was commenced in the early part of May and finished in October. During these months all other night work was considered of secondary importance. Particular attention was given to the night preceding the chief minimum, and we have thirteen plates belonging to the last day of the period, or within twenty-two hours of the minimum. Three of these cover the minimum passage and belong both to the last and to the first day of the period.

It was at first intended to make use of only three plates for each of the thirteen days, as mentioned in our report of the Observatory in the *Monthly Notices* of 1896 February. But as the micrometer work upon the plates progressed, it became evident that nearly all the plates should be used; for it was found that some details were seen on plates noted as inferior, better than on other more perfect-looking photographs. The total number of plates carefully examined is eighty-six. Some of these will be found to occupy two places in the appended catalogues of wave-lengths. In these cases half of the trailed spectrum belongs to one, and half to the following day of the light period, the whole trail being long enough to represent two separate exposures.

The slitless spectrograph employed for the series has been already fully described, partly in the *Memoirs*, vol. li, and partly in the *Monthly Notices*, vol. lvi. It is the spectrograph which was used for the *Nova* of 1892, with the alteration mentioned in the report of 1896 February. Great attention was given to this alteration, and we are largely indebted to Mr. Hilger for the expeditious way in which he helped the successive steps by which we finally arrived at the true configuration and relative densities of the component glasses for bringing the rays between D and H parallel on to the prism.

The greater stability of the instrument, owing to this alteration, has proved to be a great gain. The concave collimator having to take the cone of light before it arrives at the focal plane of the object glass, we have, in place of a long appendage to the eye end of the telescope tube, a short compact spectrograph fitted into a massive metal holder firmly screwed up in the position of an ordinary eye-piece. Its behaviour in different positions of the telescope is shown by the following scale readings for the prominent lines in the bright stars :—

	Arcturus. Mm.	α Persei. Mm.	Capella. Mm.
D	84·65	84·66	84·65
F	79·55	79·55	79·55
G′	74·63	74·63	74·63
h	71·26	71·26	71·26
H	68·86	68·88	68·86

This appears to be as accurate as can be expected in so short a length as 15·8 mm. from D to H.

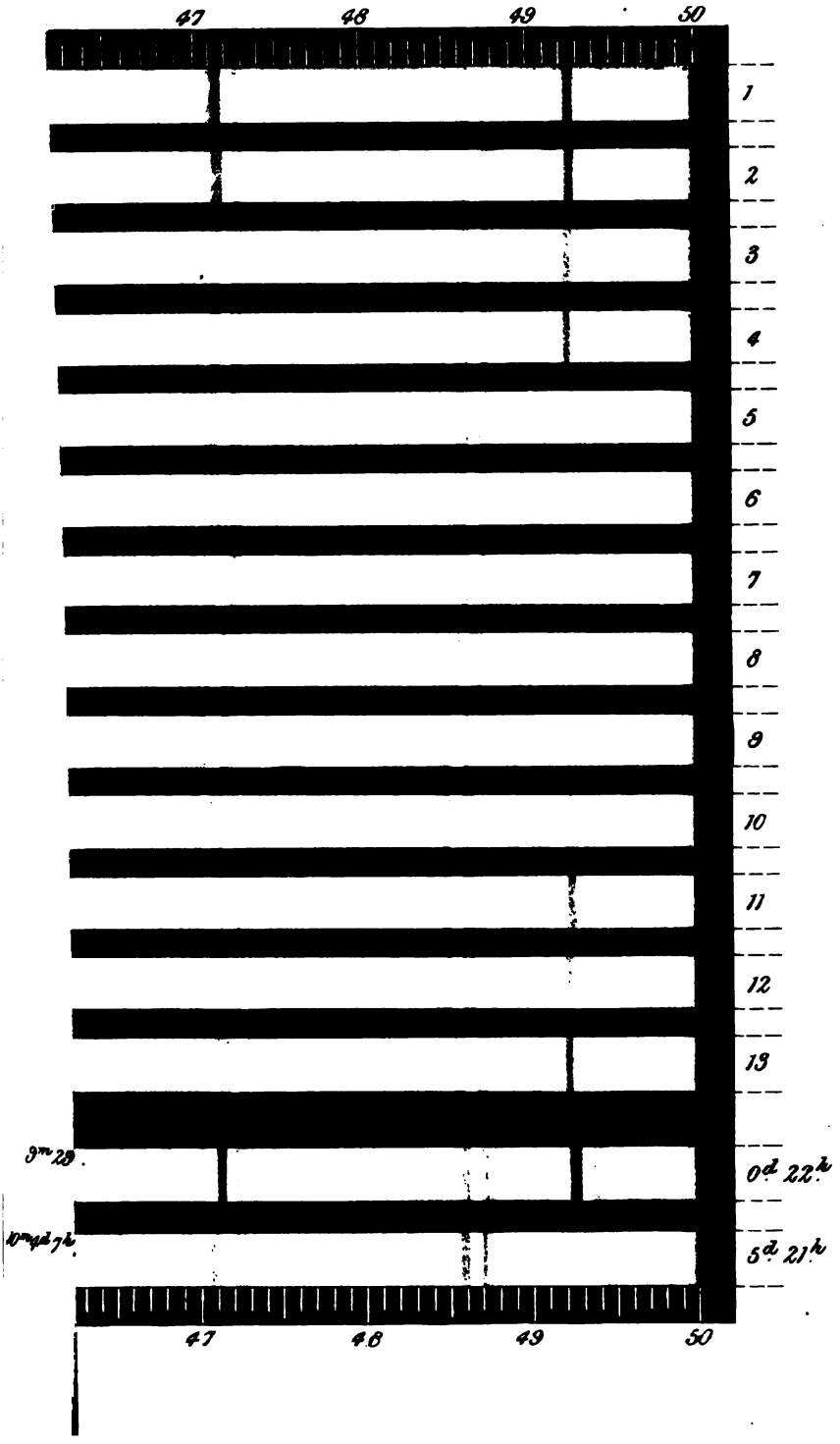
The first measurements were nearly complete at the end of 1895, but the full discussion of the series, allowing for considerable and unavoidable interruptions, has occupied a much longer time than was anticipated.

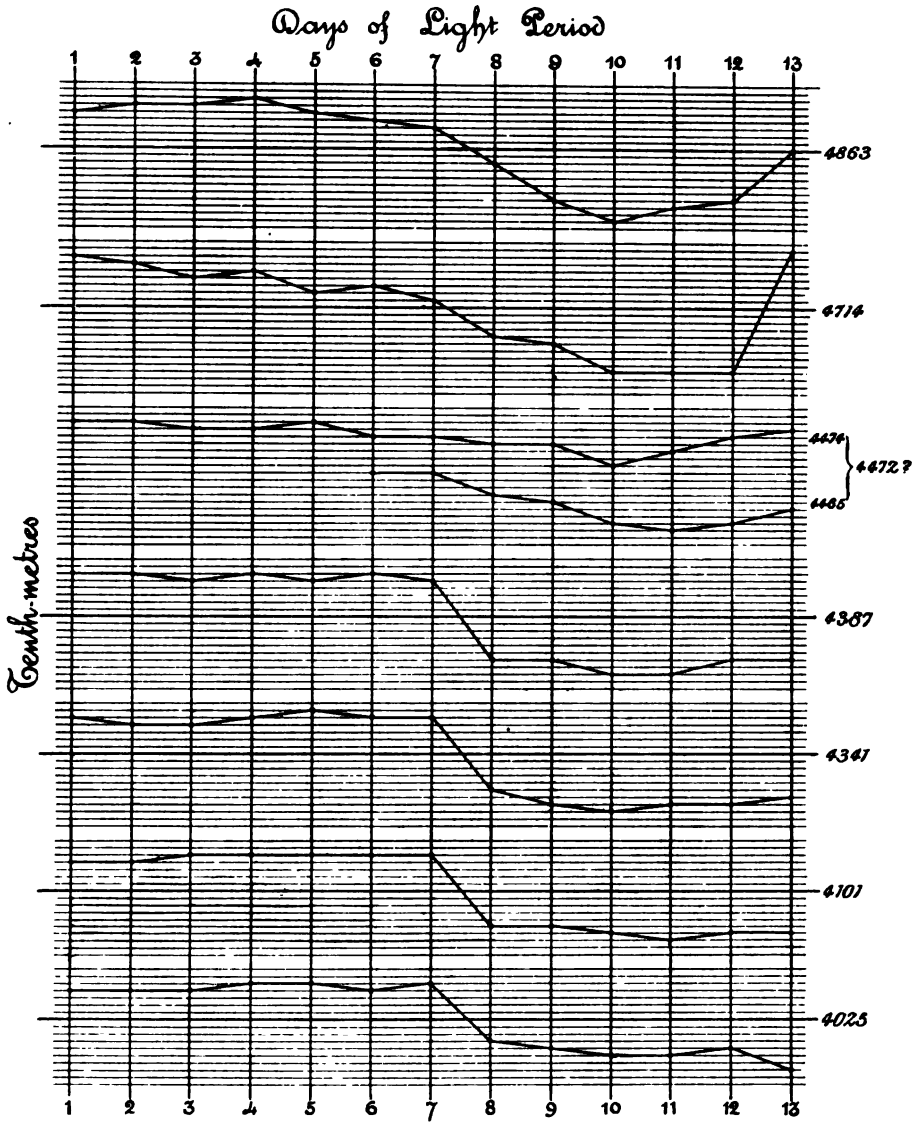
At the commencement of the work an attempt was made to show every detail of each plate on square ruled paper, and the result from fourteen plates charted in this way was an average of sixty groups of lines. But the greater number of these were too feeble to give any hope of tracing their variations with reliable accuracy; and it was decided to confine our attention to the more prominent ones. Thirteen groups were then selected for careful measurement, and the rest were left to the general remarks of the observer.

An inspection of the tables of figures will show that everything has been entered to enable the reader to form his own conclusions about the final table of mean wave-lengths, and the accompanying map of the selected lines for each day of the period. The plates are entered in the order of their time intervals from the preceding chief minimum, and their absolute dates are written in the last column, together with a note of their photographic excellence, g. meaning good, and v. very. The figures are tenth metres, and the small letters written over them* note the degree of uncertainty about them. A dash, in place of a number, explained at the foot of the table as inconclusive, means that the condition of the line, owing to a local weakness or blemish on the plate, could not be certified. It should further be observed, with reference to the note "probable," that the lines marked thus may be prudently accepted as certain: the distinction between a certain and a probable line being that the latter admits, of itself, the interpretation of contrast-effect, and is decided by its appearance on other plates in which this interpretation is inadmissible.

All the positions quoted in the tables and on the map are relative to that of the absorption component of H_γ, which has been adopted for the fiducial point of the curve-scale, at λ 4340. On the light-period map are shown only those lines whose changes could be followed with certainty. The complete spectrum of the star is given in addition as obtained from two selected plates, one near the primary, the other near the secondary minimum.

* p. for probable, and s. for suspected.


47
48
49
50
1
2
3
4
5
6
7
8
9
10
11
12
13
9m 29.
0d. 22h.
10m 4d 7h.
5d. 21h.
47
48
49
50


Days of Light Period
1 2 3 4 5 6 7 8 9 10 11 12 13
Tenth-metres
4863
4714
4476
4472.7
4465
4387
4341
4101
4025
1 2 3 4 5 6 7 8 9 10 11 12 13

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The table of mean wave-lengths for each day shows considerable changes in the positions of the radiation lines, faithfully following the light period, while the absorption lines remain quite constant; and these mean positions are found to suffer nothing when the tables of details (pp. 522–9) are consulted. These show even more clearly that the positions of all the lines throughout the spectrum remain practically constant during the first four days after the chief minimum. On the fifth and sixth days there is a suspicion of change setting in, which becomes quite pronounced on the seventh day. The radiation lines are shifting towards the violet end of the spectrum and crossing their mean position shortly after the second minimum. On the eighth and ninth days, the wave-lengths are rapidly shortening, and reach their lowest measures on the tenth day, which is that of the second maximum. These changes are shown on the map (Plate 16)* in striking contrast with the fixed positions of the absorption lines.

The changes of the bright lines are further plotted from day to day of the light period in Plate 17, and the unsmoothed curves show, in addition to a general uniformity of all the lines, some noteworthy differences. The more abrupt shortenings of the four smaller wave-lengths between the seventh and eighth days, may be due to a greater width of these lines, which would have the effect of increasing the difference between the apparent and real centres of the lines; a difference which would be greatest at this phase of the curve when the bright line was beginning to appear on the violet side of its overlapping dark companion. The effect of superposition in concealing the real centre of the bright line has been studied by Belopolsky in H_β, and by Vogel in H_ζ; and both observers have come to the same conclusion—that the apparent doubling of the bright lines is to be attributed to the dark line cutting out the centre of the bright line; and that when the bright line is seen only on one side of the dark line, its apparent centre cannot be accepted for the true position of the line in an estimate of radial velocity; and the real centre cannot be ascertained because a constant width of the line is an inadmissible postulate.

If we could have plotted the real centres of these bright lines, the curves would have exhibited a much closer agreement with Professor Vogel's conclusion, that "only small changes, undoubtedly standing in a certain relation to the periodic variations of the star, can be observed in the relative positions of the bright and dark lines."† The curve for line 447 is an illustration of this effect. If the red side bright line ‡ had faded out when that at the violet side § began to appear, the curve would have been of the same steep form as the rest. This consideration suggested the probability that the pair of bright lines in the latter half of the light period might be parts of the same radiation; the position of

* See also pp. 530–1.
† A and A—P, 1894 May, p. 362.
‡ The radiation of group 4.
§ The radiation of group 5.

its true centre for each day would be given by the mean of the pair of figures for that day; and if we could, in a similar manner, point the true centres of the line in the first half of the period, the curve would be nearly of the form plotted for λ 4474, and the resulting indication of change of radial velocities would become comparatively small. This account of the pair of bright lines is in accord with Mr. McClean's recent explanation, that "the curious effect of displacement and doubling seen in the Helium line at w.l. 4472 appears to be due to the alternate obscuration of this line and the adjacent iron (?) line at w.l. 4482, by the shift of the corresponding diffuse emission Helium line at w.l. 4472"; * but we have no division of the bright line by the dark line 448 shown on our plates. It is more closely the same as Belopolsky's explanation of H_β†, and Vogel's H_ζ, &c.; and it seems to point out the treatment of the other radiations, needed for trimming our curves to a satisfactory uniformity. The steep slopes would then disappear, and the extreme differences would be reduced to comparatively small changes.

With this explanation the groups 4 and 5 should be altered: the dark line 448 of group 4 should stand by itself, and group 5 should contain the remaining three columns.

Of the other groups ‡ the following remarks from the observer's note-book are a necessary supplement to the columns of relative wave-lengths, which contain only the line or lines which could be followed safely with the micrometer.

Group 1 at λ 492.—Only one line, a dark one, of this group is entered in the tables. It has probably a bright companion on its red side, apparently always in the same position, and if it be a real line it differs from all the other radiations in keeping the same relative position as the absorption lines.

The group falls very near the red side limit of photographic sensibility, and required very careful attention. The absorption line is broad, nearly 5 tenth-metres in width. That it fades gradually during the first four days, and recovers in the last three, rests upon the percentage of certain, probable, and suspected positions for each day; and its weakness between days 5 and 10 inclusive is shown by its complete absence from twenty-eight out of thirty-three plates belonging to this interval: of the five exceptions only two show it as probable on July 6 and September 25; the remaining three are barely suspected.

It is possible that these exceptions may be due to some period of longer duration than that of the light changes; but it can hardly be doubted that the intensity of the absorption is mainly

* *M.N.* vol. lvii. p. 7.

† *Mélanges Mathématiques et Astronomiques*, vol. vii. p. 427.

‡ In the original MS. the order of decreasing wave-lengths of the spectral lines was observed, both in the tables of figures and on the maps. It was decided to reverse the maps and the columns of figures for the press. But it was too late to re-arrange the text; and for this reason the numbers of the columns appear in the reverse order, from right to left.

under some influence closely connected with the light period; and we have, so far, no clue to any longer period: for neither of the months, July or September, can be accepted as epochs of such a period, since of the twelve plates obtained in July and twenty-five in September there are no confirmations of the positive probable exceptions.

The radiation companion is also broad like the absorption, and appears to follow the same changes of intensity, inasmuch as it is noted only for the days of the first and last quarter of the period.

Group 2 at λ 486.—Of this group only bright H_β is shown. It is broad and strong, with a fluctuating intensity, which may, at this part of the spectrum, be a photographic difficulty, but appearing strongest at the chief minimum. It is terminated on each side by a weak though broad absorption line; and of the two absorptions the blue side one is the stronger during the first half of the light period, and is strongest at the first maximum, while the other on the red side is stronger in the second half and strongest at the second maximum. This looks like the reverse of Belopolsky's observations of the same line. Here we seem to have a broader absorption cut in two by a less broad radiation, the two dark components alternately both widening and strengthening as the bright line shifts to the opposite side. But this interpretation can hardly be admitted, because on two plates between the chief minimum and first maximum we have the bright line noted as divided, with the red side component the narrower and weaker on August 22 and September 30, and two plates just after the first maximum on June 20 show a probable double with equal components.

Group 3 at λ 471.—The absorption line of this group appears clearly at the chief minimum, beginning, it would seem, at eight hours before and vanishing at the end of the second day after it. It is absent on all the intervening days if we may neglect its positions entered λ 470 as more probably belonging to another origin. It may be completely masked by the bright line during this interval, and only appear when the bright line is at its greatest red-side displacement. The bright line is notably wider with diffuse and hazy edges, shortly after the second minimum, when the two centres are together, and might be divided if the dark line were stronger. This appearance of a double bright line is noted as very probable on June 12, the ninth day of the period; and again on September 12, the tenth day, the components in each case being nearly equal, but that at the red side slightly the narrower and weaker. So far, therefore, the superposition hypothesis suits this group, but the changes of intensity do not favour it. The bright line is extremely weak near the principal minimum, and is quite extinct at the precise hour of the minimum; while it is strongest just after second minimum.

Groups 4 and 5.—Of these two groups, which have been

already fully discussed as one group, it is only necessary to add that both the dark components appear to spring suddenly up to their strongest either at, or shortly before, the principal minimum, agreeing with Vogel's observation * of H_ζ. The extreme weakness of the absorption line 448 on day 5 is very remarkable. There are four good plates for this day, one taken in May, two in September, and one in October; and it is only barely suspected on two out of the four.

Groups 6, 12, and 13 agree with group 3 in the extreme weakness of the radiation at the first minimum, but differ in being also very weak at and after the second minimum. But they show no signs of widening or dividing.

Group 7.—Both the radiation and absorption components of H_γ are very strong between the chief minimum and first maximum. The absorption is weaker during the second half of the period, and is very feeble at both minima. A weaker absorption on the red side of the hydrogen pair remains nearly constant throughout the period.

The radiation is nearly, if not quite, extinct at both minima. Its brightness fades continuously between the preceding maximum and the minimum phases, and recovers abruptly shortly after each minimum. These variations are in striking contrast with the comparatively constant radiation intensity of H_β. A careful re-examination of the best plates shows that this discordance between the two hydrogen lines cannot be attributed to the difference between the photographic sensibility at the two parts of the spectrum; there is no appearance of over-exposure at the position of H_γ.

Group 8 at λ 423.—This absorption line, like that at λ 448, is quite extinct on day 5. No trace of it is found on the same four plates already quoted for the line 448 of group 4. A feeble radiation line has also been noted as probable or suspected on some of the plates belonging to the period from just before the first minimum to the first maximum, always on the red side of the absorption.

Group 9.—This appears always as a single absorption line, except on July 27, second day after first minimum, when there is probably a radiation companion on the red side; and on two plates of June 30, just after first minimum, it appears unusually wide and probably divided.

Group 10.—A radiation line is noted as probable on the red side of this dark line on June 30 only, just after chief minimum. The absorption line has been noted as probably double on the following days:

Day 2, June 5.

„ 2, July 1, on two plates. Red side component wider.

„ 4, June 20. Both components equal.

* A and A–P, 125, p. 363.

Day 4, July 3. Red side component narrower.
„ 5, Sept. 20. „ „ „
„ 13, July 12. Blue side component very narrow and weak.

To conclude, we may ask and endeavour to answer the question: what has been added to our knowledge of this variable star since our first attempts upon its spectrum with the weaker light-power in 1893? If we confine our attention to our own observations the answer is ready, that we have neither more nor less than a confirmation of the conclusions stated in our report of the earlier work,* including the suggestion of tidal action as the cause of the bright line origins, and the claims for an elongated ellipse in place of a circular orbit. The exceptional absences of lines from plates which ought to show them if existent, at times when they usually appear, may be accounted for by the complex movements of more than two stars. They are more easily explained by the natural variations attending the periodic evolution of heat by tidal action at the periastron. The abrupt changes, both of intensity and position, at the chief minimum as compared with the slower changes at the secondary minimum are very significant; the velocity at the first must be greatly in excess of that at the second minimum, which is inconsistent with circular motion. The constancy of the spectrum, both in the strength and position of the lines, during the first quarter of the period beginning at the middle of the first day indicates, on the one hand, the first days of renewed heat energy, and, on the other, a sharp curve in the orbit at periastron, and the general weakness of the radiation lines in the latter half of the period is more in keeping with the cooling process of the bright line star than with the shading of superpositions. This view of the state of things with β *Lyræ* is at least not opposed to Belopolsky's conclusion: "En général il faut avouer que l'ensemble des faits, que l'on observe dans le spectre de cette étoile, est loin d'être expliqué par un mouvement des corps sur des orbites; il faudra toujours dans l'explication revenir aux procédés intérieurs." †

* *M.N.* vol. liv. pp. 98–99.
† *Mélanges Mathématiques et Astronomiques*, vol. vii. p. 446.

Wave-lengths and Intensities of Selected Groups in the Spectrum of β.

	Day Age from Principal Minimum.	13 Rad. λ	13 Rad. i	13 Abs. λ	13 Abs. i	12 Rad. λ	12 Rad. i	12 Abs. λ	12 Abs. i	11 Abs. λ	11 Abs. i	10 Abs. λ	10 Abs. i	9 Abs. λ	9 Abs. i	8 Abs. λ	8 Abs. i	7 Rad. λ	7 Rad. i	
	d. h.	40		40		41		41		41		41		41		42		43		4
1	0 0			26	6			02	6	21	2	30	3	46	4	35	2			
	0 0			26	4			03	5	21	2	30	3	45	4	35	3			
	0 2			26	6			02	5	22	2	30	3	45	5	35	3	46	3	
	0 11	–	–	25	6	s	–	01	8	21	2	31	3	44	3	35	3	47	10	
	0 12	–	–	25	10	s	–	01	10	20	2	30	4	43	4	36	2	46	8	
	0 22	29	4	25	10	05P	4	01	10	21	5	30	5	43	9	35	4	45	10	
Means	...	29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46	5	
2	1 8	–	–	26	6	–	–	01	10	21	3	30	4	44	4	34	2	46	8	
	1 9	30P	2	26	10	06P	2	02	10	22	2	31	3	44	3	35P	2	46	6	
	1 9	–	–	26	8	–	–	02	10	21	2	31	4	45	4	34	2	45	3	
	1 12	–	–	26	6	s	–	02	10	22	2	30	3	45	3	35	2	45	8	
	1 12	–	–	26	10	s	–	01	10	22	3	31	4	44	4	34	3	45	6	
	1 15	29P	2	25	9	05s	–	01	10	20	3	29	4	44	6	34	3	46	8	
	1 18	29P	3	25	6	05P	2	00	10	20	3	29	4	44	5	33	4	45	10	
	1 22	29P	2	26	8	05P	2	01	10	21	2	30	3	43	4	33	2	45	8	
	1 23	29P	3	25	10	05P	2	01	10	20	2	30	3	43	4	34	2	45	8	
Means	...	29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45	7	
3	2 3	30s	–	26	6	06s	–	01	10	21	2	30	3	44	4	33	2	45	10	
	2 5	30s	–	26	6	06s	–	01	10	20	2	29	3	43	4	35	1	46	10	
	2 7	30s	–	26	5	05s	–	01	10	20	2	30	3	44	3	35	2	45	8	
	2 8	29s	–	25	6	05s	–	01	10	20	2	30	3	43	3	33	1	45	10	
	2 8	–	–	26	6	06s	–	02	10	21	2	30	1	43	2	35	2	46	10	
	2 9	30s	–	26	6	06P	2	01	10	20	2	30	3	44	3	35	2	46	10	
	2 10	29P	2	26	5	06s	–	01	10	20	2	30	2	44	3	35	2	45	8	
Means	...	29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45	9	
		40		40		41		41		41		41		41		42		43		43

s = suspected
Dash = inconclusive } Excluded from means.
i = intensity, 10 = the maximum.

a series of Photographs obtained at Stonyhurst College Observatory.

6			5		4		3		2	1	
Abs.			Rad.	Abs.	Rad.	Abs.	Rad.	Abs.	Rad.	Abs.	Date, &c. 1895.
λ	ι		λ ι	λ ι	λ ι	λ ι	λ ι	λ ι	λ ι	λ ι	m. d. h.
43			44	44	44	44	47	47	48	49	
88	5			69 4	75 6	80 4		15 1	68 10	23 4	9 15 11¾, v.g.
89	6			71 3	77 4	81 3	09s –	– –	68 10	26 4	9 28 10 „
88	9			69 5	75 5	80 5		13 4	65 10	– –	10 24 8 „
88	6			70 8	77 10	82 3	– –	13 4	69 8	24 2	6 30 10-50 „
88	10			71 10	76 8	81 4	– –	13 4	71 8	24 3	6 30 11-45 „
88	10			70 10	76 10	80 4	21 3	13 4	69 10	26 9	9 29 8, perfect
88	8			70 7	76 7	81 4	21 1	13 3	68 9	25 4	
87	9			69 10	75 10	78 4	19P 2	13 4	68 6	26 3	6 5 11¾, fair
87	8			70 8	76 10	81 3	21 4	13 4	71 6	– –	6 5 12½ „
88	5			69 4	75 6	79 4		12 2	69 4	27P2	6 18 11, g.
88	5			70 6	76 10	79 4	18P 2	13 1	69 2	24P2	7 1 12 „
87	4			70 6	75 10	79 2	19s –	13s–	69 2	24s–	7 1 12 „
88	6			70 7	76 10	80 3	21P 2	15s–	71 3	26 3	7 27 11 „
88	6			69 6	76 10	80 3	21P 2	15P2	71 6	26 4	8 22 10, v.g.
87	4			69 5	75 6	78P2	21 3	– –	68 6	23 4	9 30 8, g.
88	4			70 4	76 10	78P2	22 2	15 2	69 8	26 4	9 30 9, v.g.
88	6			70 6	79 3	76 9	20 2	14 3	69 5	25 3	
87	4			69 4	75 10	78P2	18 2	13 2	68 6	23 3	10 26 9, v.g.
87	4			69 3	76 10	78s–	21s –		69 6	23 3	5 11 13 „
88	3			70 3	75 10	78s–	17 6		69 4	24s–	6 6 11 „
86	3			69 3	75 6	78s–	– –	– –	68 4		6 6 11½, g.
88	3			70 3	75 10	80s–	s –	– –	69 10	23s–	6 6 11½, poor
88	3			70 3	76 10	78s–	19P 2		69 6	– –	6 19 11, fair
88	3			70 3	75 10	78s–	19 4		71 4	– –	6 19 11½, g.
87	3			70 3	75 9	78P2	18 4		69 6	23 2	
43		44		44	44	44	47	47	48	49	

P = probable.
Blank = no line.

Day Age from Principal Minimum.		13				12				11		10		9		8		7			
		Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		Abs.	
		λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	
	d. h.	40		40		41		41		41		41		41		42		43		43	
4	3 7	29s	–	25	6	s	–	01	10	20	2	30	2	44	3	s	–	46	10	40	
	3 8	29s	–	25	4	05	10	01	10	20	2	28	3	42	4	s	–	46	10	40	
	3 9	30	5	26	6	06	4	01	10	20	2	30	3	43	3	35P	2	46	10	40	
	3 11	s	–	26	5	06P	2	01	10	20	2	30	4	43	4	34	2	46	6	40	
	3 12	30s	–	25	5	s	–	02	10	20	2	29	3	43	3	s	–	46	6	40	
	3 15	30s	–	25	6	06P	2	01	10	20	2	30	3	43	3	33s	–	46	8	40	
	3 17	30	4	26	4	06	4	01	10	21	2	30	2	43	2	35	1	47	6	40	
Means ...		30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8	40	
5	4 6	30s	–	25	6	06	2	01	10	21	2	31	3	43	4			46	8	40	
	4 20	30s	–	26	5	06	6	01	10	20	2	30	3	44	3			47	10	40	
	4 20	30P	2	27	4	07	2	02	8	20	2	30	2	44	2			48	6	40	
	4 23	29P	2	25	4	06	3	01	8	20	2	30	3	43	3			45	6	40	
Means ...		30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8	40	
6	5 2			26	5			03	9	21	2	31	2	44	2	34	2	45	6	40	
	5 11			26	5			01	9	20	2	30	3	44	3	34s	–	45	6	40	
	5 18	–	–	25	2	s	–	01	–	–	–	–	–	–	–	–	–	46	4	40	
	5 21	29P	2	26	5	06s	–	02	10	21	2	30	4	44	3	34	3	46	6	40	
	6 0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7	40	
Means ...		29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6	40	
7	6 0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7	40	
	6 4	30s	–	26	4	06s	–	02	10	21	2	31	3	44	3	33	2	46	3	40	
	6 11	–	–	25	3	–	–	02	6	20	2	30	2	44	2	34P	2	45	2	40	
	6 12			25	2			01	2	20	2	30	2	43	2	–	–	46P	2	40	
	6 12	30P	2	26	4			03	6	22	2	31	3	45	3	35	2	46s	–	40	
	6 20			25	2			00	6	20	2	30	2	43	2	–	–			40s	
Means ...		30P	1	26	3			02	6	21	2	30	3	44	3	34	2	46	3	40	
		40		40		41		41		41		41		41		42		43		43	

s = suspected
Dash = inconclusive } Excluded from means.

6			5		4		3		2	1	
d.	Abs.		Rad.	Abs.	Rad.	Abs.	Rad.	Abs.	Rad.	Abs.	Date, &c. 1895.
	43		44	44	44	44	47	47	48	49	m. d. h.
6	87	3		71P 2	75 10	79s–	19 5		69 6	24 3	6 7 11¼, g.
P2	87	3		70s –	75 10	78s–	18 4		68 8	24 2	6 7 12 „
s–	88	3		71s –	75 10	79s–	– –		69 8	– –	6 20 10½, fair
P2	87	3		70P 2	75 10	79P2	16s –		71 5	26 3	7 3 10-40, g.
s–	87	2		s –	75 8	– –	– –		71 5	– –	7 3 11-40 „
P2	87	3		70 3	76 8	79 2			71 6	23 2	7 29 10½ „
P2	87	3		70s –	76 6	79s–	19 3		69 5	24P2	8 24 9 „
3	87	3		70 2	75 9	79 2	19 3		70 6	24 2	
s–	86P	2		71s –	76 6	80s–	17 4		69 6		5 26 12, g.
6	87	4		71s –	76 10	79s–	18 6		69 10		9 20 8 „
s–	87	2			76 10		16 6		68 10		9 7 10 „
P2	85	2			74 10		14 4		65 6		10 16 7 „
4	86	3			76 9		16 5		68 8		
3	88	2		s –	74 10		16 5		67 8		5 1 13, v. g.
s–	88	2	71 6		75 10	80P2	17 5		69 6		7 5 10-35, v.g.
–	–	–	69 8		74 9	– –	17 4		67 3	– –	9 8 8, v. poor
P2	88	3	69 7		75 10	80 3	17 6		68 10		10 4 7-25, v.g.
3	86	2	67 6		74 10	s–	16 6		65 10		10 17 8 „
3	88	2	69 7		74 10	80 2	17 5		67 7		
3	86	2	67 6		74 10	s–	16 6		65 10		10 17 8, v. g.
s–	87	2	68s –		74 10	80 2	16 2		67 4		5 15 11¾ „
	87	1	72 10		76 10	80 2	16 6		68 3	– –	7 6 11, poor
3s–	88	2	68 10		74 10	79 2	17 5		67 4	23P2	7 6 12, fair
3s–	88	2	69 10		75 10	s–	16 3		67 8		7 19 10-25, g.
	86s	–	67 10		73 10	78 2	10 2		62 9		9 22 8, g.
2	87	2	69 9		74 10	79 2	15 4		66 6		
3	43		44	44	44	44	47	47	48	49	

P = probable.
Blank = no line.

Day	Age from Principal Minimum.	13 Rad. λ	13 Rad. i	13 Abs. λ	13 Abs. i	12 Rad. λ	12 Rad. i	12 Abs. λ	12 Abs. i	11 Abs. λ	11 Abs. i	10 Abs. λ	10 Abs. i	9 Abs. λ	9 Abs. i	8 Abs. λ	8 Abs. i	7 Rad. λ	7 Rad. i	7 Abs. λ
	d. h.	40		40		40		41		41		41		41		42		43		43
8	7 7			26	5			02	8	21	2	30	4	45	4	33	2	36s	–	40
	7 8	–	–	26	3	–	–	02	10	22	2	30	4	45	2	s	–	36	–	40
	7 9	–	–	26	2	–	–	02	8	21	2	30	5	45	2			36s	–	40
	7 11	–	–	26	3	–	–	02	4	20	2	30	2	45	2	35	2	36s	–	40
	7 12	–	–	25	4	–	–	01	6	20	2	29	3	44	3	33	2	s	–	40
	7 15	–	–	25	4	–	–	01	10	22	2	30	4	44	4	35	3	36p	2	40
	7 18	21	–	26	3	97s	–	02	8	22	2	30	3	44	3	34	2	36	4	40
	7 21	22p	2	26	3	96p	2	01	4	21	2	30	3	44	2	34	2	36s	–	40
	7 23	–	–	27	4	98s	–	03	10	23	2	32	3	45	3	35	2	36	5	40
Means ...		22p	1	26	3	96p	1	02	8	21	2	30	3	45	3	34	2	36	4	40
9	8 8	–	–	26	4			02	8	20	2	30	3	45	3	35	2	35	2	40
	8 11	–	–	–	–	96s	–	01	4	20	2	30	2	43	2	33p	2	35p	2	40
	8 14	21s	–	25	4	96s	–	01	10	21	2	30	4	43	3	33	2	33	2	40
Means ...				26	4			01	7	20	2	30	3	44	3	34	2	34	2	40
10	9 3	–	–	26	4	s	–	01	6	20	2	29	3	43	2	s	–	34	2	40
	9 19	–	–	–	–	–	–	01	10	21	2	30	2	43	2	33	2	33	2	40
	9 20	20s	–	25	2	95s	–	01	10	19	2	30	3	44	3	34	2	33	5	40
	9 21	20s	–	26	4	95s	–	01	8	21	2	29	2	43	2	33	2	33	3	40
	9 21	20p	2	25	2	96s	–	01	10	21	2	30	3	44	3	33	2	34	3	40
	9 23	21s	–	27	3	94s	–	02	8	21	2	31	2	43	2	34	2	33	3	40
Means ...		20p	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	40
11	10 9	19s	–	25	4	94s	–	01	10	20	2	31	2	44	2	35p	2	33p	2	40
	10 18	19	2	24	4	94p	2	01	7	21	2	29	3	43	3	s	–	33p	2	40
	10 21	19s	–	25	4	96s	–	01	8	20	2	30	2	43	2			34	3	40
	10 22	21p	2	25	6	96s	–	01	8	20	2	30	2	44	2	33p	2	35	2	40
	10 23	–	–	–	–	–	–	03	6	21	2	30	2	44	2	s	–	34s	–	40
	10 23	–	–	25	3	–	–	03	10	22	2	31	2	45	2	34	2	36	2	40
Means ...		20p	2	25	4	94p	2	02	8	21	2	30	2	44	2	34p	2	34	2	40
		40		40		40		41		41		41		41		42		43		43

s = suspected
Dash = inconclusive
} Excluded from means.

6			5			4			3			2		1	
Rad.		Abs.	Rad.		Abs.	Rad.		Abs.	Rad.		Abs.	Rad.		Abs.	Date, &c. 1895.
r	t	λ t	λ	t	λ t	λ	t	λ t	λ	t	λ t	λ	t	λ t	
43			44		44	44		44	47		47	48		49	m. d. h.
	87P	2	66	10		72	10	78 3	06	6		58	9	s –	6 11 11, g.
s –	87	2	66	10		73	10	78 3	09	6		58	10		6 11 12 ,,
s –	88	2	67	10		74	10	79 2	11	6		62	6		6 24 11, fair
	87	2	68	10		74	10	79 2	11	5		62	8		7 7 10–35, g.
	85	2	66	10		73	10	78 2	09	4		60	9		7 7 12, g.
	87	2	66	6		74	6	79 3	09	4	01P2	61	6		8 11 1 ,,
	87	2	67	9		74	9	79 3	12	5	05s–	62	8		9 10 8, v. g.
s	87	2	65	8		73	8	79 2	12	4		60	10		9 23 9 ,,
ss–	88	2	66	10		73	10	80 2	13	6		62	9		10 19 7 ,,
	87	2	66	9		73	9	79 2	10	5		61	8		
s –	87	2	66	5		73	5	79 2	10	5		55	6		6 12 11¾, v. g.
ss–	86	2	64	5		73	5	78 3	11	4		55	4		6 25 13, poor
	86	2	66	3		73	3	78 2	06	4	00 2	58	4		7 21 12, fair
	86	2	65	4		73	4	78 2	09	4		56	5		
s –	87	1	62	2		71	2	77 2	06	3		50	5		5 18 11¼, g.
											46				
ss–	86	2	62	5		68	5	77 4	05	3	97P2	53	4		9 12 9, g.
ss–	86	2	62	4		70	4	78 2	06	3	98P2	54	10	s –	9 25 8, v. g.
ss–	86	2	61	5		69	5	78 2	05	5	97P2	53	10		9 12 11, g.
ss–	85	3	60	4		70	4	77 3	01	2	s –	55	6	24P2	9 25 9, v. g.
ss–	86	2	62	2		71	2	77 2	04	2		53	6		10 8 9, g.
	86	2	62	4		70	4	77 3	05	3		53	7	24P1	
sP2	87	4	63P	3	67s –	74s	–	78s–	04s	–		54	6	– –	6 27 10½, v.g.
sP2	85	3	60	4	64 2	69	4	76 2	04	4	97s–	53	10	20P2	9 13 8 ,,
ss–	86	3	61	3	67P 2	73	3	78P2	05s	–		55	4	26P2	9 13 11 ,,
ss–	85	2	61	2	66 2	72	2	77 2				57	4	24s–	9 26 10, g.
s –	87	2	–	–	68s –	s	–	79 2	–	–		57	4	29P2	9 26 11 ,,
	86	3	62P	2	67 3	72P	2	78 3	05	3		54	5	23P2	10 22 7, v.g.
sP1	86	3	61	3	66 2	72	3	78 2	05	2		55	6	25P2	
43			44		44	44		44	47		46	48		49	

P = probable.
Blank = no line.

Day Age from Principal Minimum.	13				12				11		10		9		8		7	
	Rad. λ	ι	Abs. λ	ι	Rad. λ	ι	Abs. λ	ι	Abs. λ	ι	Abs. λ	ι	Abs. λ	ι	Abs. λ	ι	Rad. λ	ι	Ab λ
	40		40		41		41		41		41		41		42		43		43
11 8			26	6			01	10	22	2	30	4	44	4	34	2	35s	–	40
11 8	21s	–	26	4	96s	–	01	8	22	2	30	3	45	3	34	2	35P	2	40
11 9			26	4			01	8	20	3	30	4	45	3	–	–	s	–	40
11 9			26	4			01	10	20	2	29	3	43	3	33	2	31	2	40
11 19			25	3			01	7	20	2	30	2	44	2	33s	–			40
12 11 20			26	4	94P	2	01	6	20	2	30	2	43	2	s	–			40
11 21	20s	–	26	4	s	–	02	7	21	2	30	2	45	3	33	2			40
11 21	21P	2	25	5	s	–	01	10	20	2	30	3	44	3	33	2			40
11 23			26	3			02	6	21	2	31	3	44	3	s	–	35P	2	40
Means ...			26	4			01	8	21	2	30	3	44	3	33	2	34P	1	40
12 7			25	7			01	10	20	2	30	4	43	4	33	2	34s	–	40
12 8			25	7			02	10	22	2	30	4	45	4	34	2	s	–	40
12 10			26	5			02	8	21	2	30	3	44	3	33	2	34P	2	40
12 11			25	4			02	6	22	2	31	3	44	3	34	2	s	–	40
12 12			25	4			02	6	21	2	30	4	45	3	34	2	s	–	40
13 12 14	18s	–	26	6	95s	–	01	10	21	2	30	4	45	4	35	3	35P	2	40
12 17	s	–	26	8	s	–	02	8	22	2	30	3	45	4	34	2			40
12 19			26	5			02	6	22	2	31	3	45	3	s	–			40
12 20			26	5			01	6	22	2	30	2	44	2	33	2			40
12 21			27	6			02	6	22	2	32	3	45	3	35	1			40
0 0			26	6			02	6	21	2	30	3	46	4	35	2			40
Means ...			26	6			02	7	21	2	30	3	45	3	34	2	35P	1	30
	40		40		41		41		41		41		41		42		43		43

s = suspected
Dash = inconclusive } Excluded from means.

6			5		4		3		2		1		
Abs.			Rad.	Abs.	Rad.	Abs.	Rad.	Abs.	Rad.		Abs.		Date, &c. 1895.
λ		ι	λ ι	λ ι	λ ι	λ ι	λ ι	λ ι	λ	ι	λ	ι	
43			44	44	44	44	47	46	48		49		m. d. h.
87	3		– –	68	4	s –	78	3	s –	s –	55	2	24	2	6 15 12, g.
86	4		63P	2	69	4	74P	2	79	2		s –	54	4	24P	2	6 15 11½ „
87	3				68	4			80	3	04P	2	96P	2	57	2			6 15 12¾ „
87	3		– –		66	2	s –		78	2	05P	2			53	3	s –		6 15 13¼, v.g.
86	3				69	4			80	3	07s	–	99s	–	62s	–			9 27 7, g.
87	3		60P	2	68	7			79	3					60	4	21P	1	9 27 8 „
87	4				69	8			79	4					58	5	21	4	9 27 9, v.g.
86	4				68	8			79	4	s	–	s	–	55	5	20s	–	10 10 7, g.
86	3		62P	2	67	10	74P	2	78	3	04s	–	97s– 47 09s–		54	3	23	2	10 23 7, v.g.
87	3		62P	1	68	6	74P	1	79	3	05P	1			56	4	23	2	
85	4		63P	2	68	3	74P	2	78	3			-	–	58	9	21	4	6 16 10½, v.g.
87	5				69	3			80	3	21P	2	s	–	60	6	21	4	6 16 11½ „
87	4		s –		68	3	s	–	79	3	22P	2	s	–	60	4	23	3	7 12 10-25, v.g.
87	3		s –		68	3	s	–	79	3					61	9	21	4	7 12 10-40, g.
87	5		s –		68	2	74P	2	79	2	s	–			60	10	24	3	7 12 11-40, v.g.
87	5		64P	2	69	5	75P	2	79	5	s	–	13	3	64	9	24	4	8 7 10, v.g.
89	6				70	3			81	3	s	–	15	2	65	10	24	4	9 2 9, g.
88	6		64s	–	70	3	76P	2	81	3			13	2	65	10	24	4	9 15 8¾, v.g.
87	5		–	–	68	3	74	4	79	3	18s	–	13	2	64	10	20	2	9 15 10, poor.
89	4		64P	2	70	3	76	4	80	3			13	3	65	10	24	3	9 15 11-15, v.g.
88	5				69	4	75	6	80	4			15	1	68	10	23	4	9 15 11¾ „
87	5		64P	1	69	3	75	2	80	3	22P	1	14	2	63	9	23	4	
43			44		44		44		47		47		48		49				

P = probable.
Blank = no line.

Spectrum of β Lyræ, 1895, *Stonyhurst College Observatory.* **Mean**

Day	13		12		11	10	9	8	7	
	Rad.	Abs.	Rad.	Abs.	Abs.	Abs.	Abs.	Abs.	Rad.	Abs
Age.	λ i	λ i	λ i	λ i	λ i	λ i	λ i	λ i	λ i	λ
	40	40	41	41	41	41	41	42	43	43
1	29 1	26 7	05P 1	02 7	21 3	30 4	44 5	35 3	46 5	40
2	29P 2	26 8	05P 2	01 10	21 2	30 4	44 4	34 2	45 7	40
3	29P 2	26 6	06P 2	01 10	20 2	30 3	44 3	34 2	45 9	40
4	30 5	25 5	06 4	01 10	20 2	30 3	43 3	35 2	46 8	40
5	30P 2	26 5	06 3	01 9	20 2	30 3	44 3		47 8	40
6	29P 1	26 4		02 9	21 2	30 3	44 3	34 2	46 6	40
7	30P 1	26 3	40	02 6	21 2	30 3	44 3	34 2	46 3	40
8	22P 1	26 3	96P 1	02 8	21 2	30 3	45 3	34 2	36 4	40
9		26 4		01 7	20 2	30 3	44 3	34 2	34 2	40
10	20P 2	26 3		01 9	21 2	30 3	43 2	33 2	33 3	40
11	20P 2	25 4	94P 2	02 8	21 2	30 2	44 2	34P 2	34 2	40
12		26 4		01 8	21 2	30 3	44 3	33 2	34P 1	40
13		26 6		02 7	21 2	30 3	45 3	34 2	35P 1	40
	40	40	40	41	41	41	41	42	43	43
Range	10 4	1 5	12 3	1 4	1 1	0 2	2 3	2 1	14 8	0

Wave-lengths and Intensities of the Selected Groups for each Day Age.

6				5				4				3				2		1		
Rad.		Abs.		Abs.		Rad.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		No. of Plates
λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
43		43		44		44		44		44		47		47		48		49		
93P	1	88	8	70	7			76	7	81	4	21	1	13	3	68	9	25	4	6
93	3	88	6	70	6			76	9	79	3	20	2	14	3	69	5	25	3	9
92P	2	87	3	70	3			75	9	78P	2	18	4			69	6	23	2	7
93	3	87	3	70	2			75	9	79	2	19	3			70	6	24	2	7
92	4	86	3					76	9			16	5			68	8			4
93	3	88	2			69	7	74	10	80	2	17	5			67	7			5
92	1	87	2			69	9	74	10	79	2	15	4			66	6			6
		87	2			66	9	73	9	79	2	10	5			61	8			9
		86	2			65	4	73	4	78	2	09	4			56	5			4
		86	2			62	4	70	4	77	3	05	3			53	7	24P	1	5
79P	1	86	3	66	2	61	3	72	3	78	2	05	2			55	6	25P	2	6
		87	3	68	6	62P	1	74P	1	79	3	05P	1			56	4	23	2	9
81P	1	87	5	69	3	64P	1	75	2	80	3	22P	1	14	2	63	9	23	4	11
43		43		44		44		44		44		47		47		48		49		
14	3	2	6	4	5	8	8	6	9	4	2	18	4	1	1	16	5	2		

Wave-lengths and Intensities of Selected Groups in the Spectrum of β L

	Day Age from Principal Minimum.	13 Rad. λ	13 Rad. i	13 Abs. λ	13 Abs. i	12 Rad. λ	12 Rad. i	12 Abs. λ	12 Abs. i	11 Abs. λ	11 Abs. i	10 Abs. λ	10 Abs. i	9 Abs. λ	9 Abs. i	8 Abs. λ	8 Abs. i	7 Rad. λ	7 Rad. i
	d. h.	40		40		41		41		41		41		41		42		43	43
1	0 0			26	6			02	6	21	2	30	3	46	4	35	2		4
	0 0			26	4			03	5	21	2	30	3	45	4	35	3		4
	0 2			26	6			02	5	22	2	30	3	45	5	35	3	46 3	4
	0 11	–	–	25	6	s	–	01	8	21	2	31	3	44	3	35	3	47 10	4
	0 12	–	–	25	10	s	–	01	10	20	2	30	4	43	4	36	2	46 8	4
	0 22	29	4	25	10	05P	4	01	10	21	5	30	5	43	9	35	4	46 10	4
Means	...	29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46 5	4
2	1 8	–	–	26	6	–	–	01	10	21	3	30	4	44	4	34	2	46 8	4
	1 9	30P	2	26	10	06P	2	02	10	22	2	31	3	44	3	35P	2	46 6	4
	1 9	–	–	26	8	–	–	02	10	21	2	31	4	45	4	34	2	45 3	4
	1 12	–	–	26	6	s	–	02	10	22	2	30	3	45	3	35	2	45 8	4
	1 12	–	–	26	10	s	–	01	10	22	3	31	4	44	4	34	3	45 6	4
	1 15	29P	2	25	9	05s	–	01	10	20	3	29	4	44	6	34	3	46 8	4
	1 18	29P	3	25	6	05P	2	00	10	20	3	29	4	44	5	33	4	45 10	4
	1 22	29P	2	26	8	05P	2	01	10	21	2	30	3	43	4	33	2	45 8	4
	1 23	29P	3	25	10	05P	2	01	10	20	2	30	3	43	4	34	2	45 8	4
Means	...	29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45 7	4
3	2 3	30s	–	26	6	06s	–	01	10	21	2	30	3	44	4	33	2	45 10	4
	2 5	30s	–	26	6	06s	–	01	10	20	2	29	3	43	4	35	1	46 10	4
	2 7	30s	–	26	5	05s	–	01	10	20	2	30	3	44	3	35	2	45 8	4
	2 8	29s	–	25	6	05s	–	01	10	20	2	30	3	43	3	33	1	45 10	4
	2 8	–	–	26	6	06s	–	02	10	21	2	30	1	43	2	35	2	46 10	4
	2 9	30s	–	26	6	06P	2	01	10	20	2	30	3	44	3	35	2	46 10	4
	2 10	29P	2	26	5	06s	–	01	10	20	2	30	2	44	3	35	2	45 8	4
Means	...	29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45 9	4
		40		40		41		41		41		41		41		42		43	43

s = suspected
Dash = inconclusive } Excluded from means.
i = intensity, 10 = the maximum.

a series of Photographs obtained at Stonyhurst College Observatory.

	6			5			4			3			2		1		
	Abs.			Rad.	Abs.		Rad.	Abs.		Rad.	Abs.		Rad.		Abs.		Date, &c. 1895.
	λ	i		λ i	λ	i	λ i	λ	i	λ i	λ	i	λ i		λ	i	
	43		44		44		44	44		47	47		48		49		m. d. h.
	88	5			69	4	75 6	80	4		15	1	68	10	23	4	9 15 11¾, v.g.
	89	6			71	3	77 4	81	3	09s	–	– –	68	10	26	4	9 28 10 „
	88	9			69	5	75 5	80	5		13	4	65	10	–	–	10 24 8 „
	88	6			70	8	77 10	82	3	– –	13	4	69	8	24	2	6 30 10-50 „
	88	10			71	10	76 8	81	4	– –	13	4	71	8	24	3	6 30 11-45 „
p2	88	10			70	10	76 10	80	4	21 3	13	4	69	10	26	9	9 29 8, perfect
p1	88	8			70	7	76 7	81	4	21 1	13	3	68	9	25	4	
	87	9			69	10	75 10	78	4	19p 2	13	4	68	6	26	3	6 5 11¾, fair
p2	87	8			70	8	76 10	81	3	21 4	13	4	71	6	–	–	6 5 12½ „
s–	88	5			69	4	75 6	79	4		12	2	69	4	27p2		6 18 11, g.
s–	88	5			70	6	76 10	79	4	18p 2	13	1	69	2	24p2		7 1 12 „
s–	87	4			70	6	75 10	79	2	19s –	13s–		69	2	24s–		7 1 12 „
5	88	6			70	7	76 10	80	3	21p 2	15s–		71	3	26	3	7 27 11 „
3	88	6			69	6	76 10	80	3	21p 2	15p2		71	6	26	4	8 22 10, v.g.
p2	87	4			69	5	75 6	78p2		21 3	– –		68	6	23	4	9 30 8, g.
s–	88	4			70	4	76 10	78p2		22 2	15	2	69	8	26	4	9 30 9, v.g.
3	88	6			70	6	79 3	76	9	20 2	14	3	69	5	25	3	
p2	87	4			69	4	75 10	78p2		18 2	13	2	68	6	23	3	10 26 9, v.g.
s–	87	4			69	3	76 10	78s–		21s –			69	6	23	3	5 11 13 „
s–	88	3			70	3	75 10	78s–		17 6			69	4	24s–		6 6 11 „
s–	86	3			69	3	75 6	78s–		– –	– –		68	4			6 6 11½, g.
p2	88	3			70	3	75 10	80s–		s –	– –		69	10	23s–		6 6 11½, poor
p2	88	3			70	3	76 10	78s–		19p 2			69	6	–	–	6 19 11, fair
p2	88	3			70	3	75 10	78s–		19 4			71	4	–	–	6 19 11½, g.
p2	87	3			70	3	75 9	78p2		18 4			69	6	23	2	
	43		44		44		44	44		47	47		48		49		

p = probable.
Blank = no line.

Day	Age from Principal Minimum.	13 Rad. λ	13 Rad. ι	13 Abs. λ	13 Abs. ι	12 Rad. λ	12 Rad. ι	12 Abs. λ	12 Abs. ι	11 Abs. λ	11 Abs. ι	10 Abs. λ	10 Abs. ι	9 Abs. λ	9 Abs. ι	8 Abs. λ	8 Abs. ι	7 Rad. λ	7 Rad. ι	7 Abs. λ
	d. h.	40		40		41		41		41		41		41		42		43		43
4	3 7	29s	–	25	6	s	–	01	10	20	2	30	2	44	3	s	–	46	10	40
	3 8	29s	–	25	4	05	10	01	10	20	2	28	3	42	4	s	–	46	10	40
	3 9	30	5	26	6	06	4	01	10	20	2	30	3	43	3	35P	2	46	10	40
	3 11	s	–	26	5	06P	2	01	10	20	2	30	4	43	4	34	2	46	6	40
	3 12	30s	–	25	5	s	–	02	10	20	2	29	3	43	3	s	–	46	6	40
	3 15	30s	–	25	6	06P	2	01	10	20	2	30	3	43	3	33s	–	46	8	40
	3 17	30	4	26	4	06	4	01	10	21	2	30	2	43	2	35	1	47	6	40
Means	...	30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8	40
5	4 6	30s	–	25	6	06	2	01	10	21	2	31	3	43	4			46	8	40
	4 20	30s	–	26	5	06	6	01	10	20	2	30	3	44	3			47	10	40
	4 20	30P	2	27	4	07	2	02	8	20	2	30	2	44	2			48	6	40
	4 23	29P	2	25	4	06	3	01	8	20	2	30	3	43	3			45	6	40
Means	...	30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8	40
6	5 2			26	5			03	9	21	2	31	2	44	2	34	2	45	6	40
	5 11			26	5			01	9	20	2	30	3	44	3	34s	–	45	6	40
	5 18	–	–	25	2	s	–	01	–	–	–	–	–	–	–	–	–	46	4	40
	5 21	29P	2	26	5	06s	–	02	10	21	2	30	4	44	3	34	3	46	6	40
	6 0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7	40
Means	...	29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6	40
7	6 0	30s	–	26	3	06s	–	01	8	21	2	30	3	44	3	33	2	47	7	40
	6 4	30s	–	26	4	06s	–	02	10	21	2	31	3	44	3	33	2	46	3	40
	6 11	–	–	25	3	–	–	02	6	20	2	30	2	44	2	34P	2	45	2	40
	6 12			25	2			01	2	20	2	30	2	43	2	–	–	46P	2	40
	6 12	30P	2	26	4			03	6	22	2	31	3	45	3	35	2	46s	–	40
	6 20			25	2			00	6	20	2	30	2	43	2	–	–			40s
Means	...	30P	1	26	3			02	6	21	2	30	3	44	3	34	2	46	3	40
		40		40		41		41		41		41		41		42		43		43

s = suspected
Dash = inconclusive
} Excluded from means.

6				5				4				3				2		1		
Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Date, &c. 1895.
λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	λ	ſ	
43		43		44		44		44		44		47		47		48		49		m. d. h.
93	6	87	3			71P	2	75	10	79s–		19	5			69	6	24	3	6 7 11¼, g.
93P	2	87	3			70s	–	75	10	78s–		18	4			68	8	24	2	6 7 12 „
94s–		88	3			71s	–	75	10	79s–		–	–			69	8	–	–	6 20 10½, fair
93P	2	87	3			70P	2	75	10	79P	2	16s	–			71	5	26	3	7 3 10-40, g.
92s–		87	2			s	–	75	8	–	–	–	–			71	5	–	–	7 3 11-40 „
92P	2	87	3			70	3	76	8	79	2					71	6	23	2	7 29 10½ „
92P	2	87	3			70s	–	76	6	79s–		19	3			69	5	24P	2	8 24 9 „
93	3	87	3			70	2	75	9	79	2	19	3			70	6	24	2	
93s–		86P	2			71s	–	76	6	80s–		17	4			69	6			5 26 12, g.
92	6	87	4			71s	–	76	10	79s–		18	6			69	10			9 20 8 „
s–		87	2					76	10			16	6			68	10			9 7 10 „
92P	2	85	2					74	10			14	4			65	6			10 16 7 „
92	4	86	3					76	9			16	5			68	8			
93	3	88	2	s	–			74	10			16	5			67	8			5 1 13, v. g.
94s–		88	2	71	6			75	10	80P	2	17	5			69	6			7 5 10-35, v.g.
–	–	–	–	69	8			74	9	–	–	17	4			67	3	–	–	9 8 8, v. poor
94P	2	88	3	69	7			75	10	80	3	17	6			68	10			10 4 7-25, v.g.
92	3	86	2	67	6			74	10	s–		16	6			65	10			10 17 8 „
93	3	88	2	69	7			74	10	80	2	17	5			67	7			
92	3	86	2	67	6			74	10	s–		16	6			65	10			10 17 8, v. g.
90s–		87	2	68s	–			74	10	80	2	16	2			67	4			5 15 11¾ „
		87	1	72	10			76	10	80	2	16	6			68	3	–	–	7 6 11, poor
93s–		88	2	68	10			74	10	79	2	17	5			67	4	23P	2	7 6 12, fair
93s–		88	2	69	10			75	10	s–		16	3			67	8			7 19 10-25, g.
		86s	–	67	10			73	10	78	2	10	2			62	9			9 22 8, g.
92	1	87	2	69	9			74	10	79	2	15	4			66	6			
43		43		44		44		44		44		47		47		48		49		

P = probable.
Blank = no line.

Day Age from Principal Minimum.		13				12				11		10		9		8		7			
		Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		Abs.	
		λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t
	d. h.	40		40		40		41		41		41		41		42		43		43	
8	7 7			26	5			02	8	21	2	30	4	45	4	33	2	36s	–	40	3
	7 8	–	–	26	3	–	–	02	10	22	2	30	4	45	2	s	–	36	–	40	4
	7 9	–	–	26	2	–	–	02	8	21	2	30	5	45	2			36s	–	40	4
	7 11	–	–	26	3	–	–	02	4	20	2	30	2	45	2	35	2	36s	–	40	3
	7 12	–	–	25	4	–	–	01	6	20	2	29	3	44	3	33	2	s	–	40	3
	7 15	–	–	25	4	–	–	01	10	22	2	30	4	44	4	35	3	36p	2	40	6
	7 18	21	–	26	3	97s	–	02	8	22	2	30	3	44	3	34	2	36	4	40	4
	7 21	22p	2	26	3	96p	2	01	4	21	2	30	3	44	2	34	2	36s	–	40	2
	7 23	–	–	27	4	98s	–	03	10	23	2	32	3	45	3	35	2	36	5	40	5
Means ...		22p	1	26	3	96p	1	02	8	21	2	30	3	45	3	34	2	36	4	40	4
9	8 8	–	–	26	4			02	8	20	2	30	3	45	3	35	2	35	2	40	4
	8 11	–	–	–	–	96s	–	01	4	20	2	30	2	43	2	33p	2	35p	2	40	5
	8 14	21s	–	25	4	96s	–	01	10	21	2	30	4	43	3	33	2	33	2	40	3
Means ...				26	4			01	7	20	2	30	3	44	3	34	2	34	2	40	4
10	9 3	–	–	26	4	s	–	01	6	20	2	29	3	43	2	s	–	34	2	40	4
	9 19	–	–	–	–	–	–	01	10	21	2	30	2	43	2	33	2	33	2	40	4
	9 20	20s	–	25	2	95s	–	01	10	19	2	30	3	44	3	34	2	33	5	40	6
	9 21	20s	–	26	4	95s	–	01	8	21	2	29	2	43	2	33	2	33	3	40	4
	9 21	20p	2	25	2	96s	–	01	10	21	2	30	3	44	3	33	2	34	3	40	5
	9 23	21s	–	27	3	94s	–	02	8	21	2	31	2	43	2	34	2	33	3	40	4
Means ...		20p	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	40	5
11	10 9	19s	–	25	4	94s	–	01	10	20	2	31	2	44	2	35p	2	33p	2	40	8
	10 18	19	2	24	4	94p	2	01	7	21	2	29	3	43	3	s	–	33p	2	40	4
	10 21	19s	–	25	4	96s	–	01	8	20	2	30	2	43	2			34	3	40	8
	10 22	21p	2	25	6	96s	–	01	8	20	2	30	2	44	2	33p	2	35	2	40	5
	10 23	–	–	–	–	–	–	03	6	21	2	30	2	44	2	s	–	34s	–	40	4
	10 23	–	–	25	3	–	–	03	10	22	2	31	2	45	2	34	2	36	2	40	7
Means ...		20p	2	25	4	94p	2	02	8	21	2	30	2	44	2	34p	2	34	2	40	6
		40		40		40		41		41		41		41		42		43		43	

s = suspected
Dash = inconclusive
} Excluded from means.

6			5			4			3			2		1	
Rad.	Abs.		Rad.	Abs.		Rad.	Abs.		Rad.	Abs.		Rad.		Abs.	Date, &c. 1895.
ſ	λ	ſ	λ	ſ	λ ſ	λ	ſ	λ ſ	λ	ſ	λ ſ	λ	ſ	λ ſ	
	43		44		44	44			47		47	48		49	m. d. h.
	87P	2	66	10		72	10	78 3	06	6		58	9	s –	6 11 11, g.
s –	87	2	66	10		73	10	78 3	09	6		58	10		6 11 12 ,,
s –	88	2	67	10		74	10	79 2	11	6		62	6		6 24 11, fair
	87	2	68	10		74	10	79 2	11	5		62	8		7 7 10–35, g.
	85	2	66	10		73	10	78 2	09	4		60	9		7 7 12, g.
	87	2	66	6		74	6	79 3	09	4	01P2	61	6		8 11 1 ,,
	87	2	67	9		74	9	79 3	12	5	05s–	62	8		9 10 8, v. g.
	87	2	65	8		73	8	79 2	12	4		60	10		9 23 9 ,,
8s–	88	2	66	10		73	10	80 2	13	6		62	9		10 19 7 ,,
	87	2	66	9		73	9	79 2	10	5		61	8		
s –	87	2	66	5		73	5	79 2	10	5		55	6		6 12 11¾, v. g.
8s–	86	2	64	5		73	5	78 3	11	4		55	4		6 25 13, poor
	86	2	66	3		73	3	78 2	06	4	00 2	58	4		7 21 12, fair
	86	2	65	4		73	4	78 2	09	4		56	5		
s –	87	1	62	2		71	2	77 2	06	3		50	5		5 18 11¼, g.
											46				
9s–	86	2	62	5		68	5	77 4	05	3	97P2	53	4		9 12 9, g.
0s–	86	2	62	4		70	4	78 2	06	3	98P2	54	10	s –	9 25 8, v. g.
9s–	86	2	61	5		69	5	78 2	05	5	97P2	53	10		9 12 11, g.
9s–	85	3	60	4		70	4	77 3	01	2	s –	55	6	24P2	9 25 9, v. g.
9s–	86	2	62	2		71	2	77 2	04	2		53	6		10 8 9, g.
	86	2	62	4		70	4	77 3	05	3		53	7	24P1	
79P2	87	4	63P	3	67s –	74s	–	78s–	04s	–		54	6	– –	6 27 10½, v.g.
79P2	85	3	60	4	64 2	69	4	76 2	04	4	97s–	53	10	20P2	9 13 8 ,,
8is–	86	3	61	3	67P 2	73	3	78P2	05s	–		55	4	26P2	9 13 11 ,,
78s–	85	2	61	2	66 2	72	2	77 2				57	4	24s–	9 26 10, g.
s –	87	2	–	–	68s –	s	–	79 2	–	–		57	4	29P2	9 26 11 ,,
	86	3	62P	2	67 3	72P	2	78 3	05	3		54	5	23P2	10 22 7, v.g.
79P1	86	3	61	3	66 2	72	3	78 2	05	2		55	6	25P2	
8	43		44		44	44		44	47		46	48		49	

P = probable.
Blank = no line.

Day Age from Principal Minimum.	13				12				11		10		9		8		7	
	Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.	Abs.
	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	t	λ	λ
	40		40		41		41		41		41		41		42		43	43
	11 8		26	6			01	10	22	2	30	4	44	4	34	2	35s –	40
	11 8	21s –	26	4	96s –		01	8	22	2	30	3	45	3	34	2	35P 2	40
	11 9		26	4			01	8	20	3	30	4	45	3	–	–	s –	40
	11 9		26	4			01	10	20	2	29	3	43	3	33	2	31 2	40
	11 19		25	3			01	7	20	2	30	2	44	2	33s –			40
12	11 20		26	4	94P 2		01	6	20	2	30	2	43	2	s –			40
	11 21	20s –	26	4	s –		02	7	21	2	30	2	45	3	33	2		40
	11 21	21P 2	25	5	s –		01	10	20	2	30	3	44	3	33	2		40
	11 23		26	3			02	6	21	2	31	3	44	3	s –		35P 2	40
Means ...			26	4			01	8	21	2	30	3	44	3	33	2	34P 1	40
	12 7		25	7			01	10	20	2	30	4	43	4	33	2	34s –	40
	12 8		25	7			02	10	22	2	30	4	45	4	34	2	s –	40
	12 10		26	5			02	8	21	2	30	3	44	3	33	2	34P 2	40
	12 11		25	4			02	6	22	2	31	3	44	3	34	2	s –	40
	12 12		25	4			02	6	21	2	30	4	45	3	34	2	s –	40
13	12 14	18s –	26	6	95s –		01	10	21	2	30	4	45	4	35	3	35P 2	40
	12 17	s –	26	8	s –		02	8	22	2	30	3	45	4	34	2		40
	12 19		26	5			02	6	22	2	31	3	45	3	s –			40
	12 20		26	5			01	6	22	2	30	2	44	2	33	2		40
	12 21		27	6			02	6	22	2	32	3	45	3	35	1		40
	0 0		26	6			02	6	21	2	30	3	46	4	35	2		40
Means ...			26	6			02	7	21	2	30	3	45	3	34	2	35P 1	30
	40		40		41		41		41		41		41		42		43	43

s = suspected
Dash = inconclusive } Excluded from means.

6			5			4			3			2		1	
Rad.	Abs.		Rad.	Abs.		Rad.	Abs.		Rad.	Abs.		Rad.		Abs.	Date, &c. 1895.
i	λ	i	λ	i		λ	i		λ	i		λ	i	λ i	
43			44	44		44	44		47	46		48		49	m. d. h.
	87	3	– –	68	4	s –	78	3	s –	s –		55	2	24 2	6 15 12, g.
P2	86	4	63P 2	69	4	74P 2	79	2		s –		54	4	24P2	6 15 11½ ,,
–	87	3		68	4		80	3	04P 2	96P2		57	2		6 15 12¾ ,,
	87	3	– –	66	2	s –	78	2	05P 2			53	3	s –	6 15 13¼, v.g.
	86	3		69	4		80	3	07s –	99s–		62s	–		9 27 7, g.
–	87	3	60P 2	68	7		79	3				60	4	21P1	9 27 8 ,,
	87	4		69	8		79	4				58	5	21 4	9 27 9, v.g.
	86	4		68	8		79	4	s –	s –		55	5	20s–	10 10 7, g.
s–	86	3	62P 2	67	10	74P 2	78	3	04s –	97s– 47 09s–		54	3	23 2	10 23 7, v.g.
	87	3	62P 1	68	6	74P 1	79	3	05P 1			56	4	23 2	
s–	85	4	63P 2	68	3	74P 2	78	3		- –		58	9	21 4	6 16 10½, v.g.
s –	87	5		69	3		80	3	21P 2	s –		60	6	21 4	6 16 11½ ,,
s –	87	4	s –	68	3	s –	79	3	22P 2	s –		60	4	23 3	7 12 10-25, v.g.
	87	3	s –	68	3	s –	79	3				61	9	21 4	7 12 10-40, g.
	87	5	s –	68	2	74P 2	79	2	s –			60	10	24 3	7 12 11-40, v.g.
2P2	87	5	64P 2	69	5	75P 2	79	5	s –	13 3		64	9	24 4	8 7 10, v.g.
	89	6		70	3		81	3	s –	15 2		65	10	24 4	9 2 9, g.
1P2	88	6	64s –	70	3	76P 2	81	3		13 2		65	10	24 4	9 15 8¾, v.g.
1P2	87	5	– –	68	3	74 4	79	3	18s –	13 2		64	10	20 2	9 15 10, poor.
	89	4	64P 2	70	3	76 4	80	3		13 3		65	10	24 3	9 15 11-15, v.g.
	88	5		69	4	75 6	80	4		15 1		68	10	23 4	9 15 11¾ ,,
1P1	87	5	64P 1	69	3	75 2	80	3	22P 1	14 2		63	9	23 4	
	43		44	44		44	44		47	47		48		49	

P = probable.
Blank = no line.

Spectrum of β Lyræ, 1895, *Stonyhurst College Observatory.* *Mean*

Day	13				12				11		10		9		8		7			
Day	Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		Ab	
Age.	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	
	40		40		41		41		41		41		41		42		43		43	
1	29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46	5	40	
2	29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45	7	40	
3	29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45	9	40	
4	30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8	40	
5	30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8	40	
6	29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6	40	
7	30P	1	26	3	40		02	6	21	2	30	3	44	3	34	2	46	3	40	
8	22P	1	26	3	96P	1	02	8	21	2	30	3	45	3	34	2	36	4	40	
9			26	4			01	7	20	2	30	3	44	3	34	2	34	2	40	
10	20P	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	40	
11	20P	2	25	4	94P	2	02	8	21	2	30	2	44	2	34P	2	34	2	40	
12			26	4			01	8	21	2	30	3	44	3	33	2	34P	1	40	
13			26	6			02	7	21	2	30	3	45	3	34	2	35P	1	40	
	40		40		40		41		41		41		41		42		43		43	
Range	10	4	1	5	12	3	1	4	1	1	0	2	2	3	2	1	14	8	0	

Wave-lengths and Intensities of the Selected Groups for each Day Age.

6				5				4				3				2		1		
Rad.		Abs.		Abs.		Rad.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		No. of Plates
λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
43		43		44		44		44		44		47		47		48		49		
93P	1	88	8	70	7			76	7	81	4	21	1	13	3	68	9	25	4	6
93	3	88	6	70	6			76	9	79	3	20	2	14	3	69	5	25	3	9
92P	2	87	3	70	3			75	9	78P	2	18	4			69	6	23	2	7
93	3	87	3	70	2			75	9	79	2	19	3			70	6	24	2	7
92	4	86	3					76	9			16	5			68	8			4
93	3	88	2			69	7	74	10	80	2	17	5			67	7			5
92	1	87	2			69	9	74	10	79	2	15	4			66	6			6
		87	2			66	9	73	9	79	2	10	5			61	8			9
		86	2			65	4	73	4	78	2	09	4			56	5			4
		86	2			62	4	70	4	77	3	05	3			53	7	24P	1	5
79P	1	86	3	66	2	61	3	72	3	78	2	05	2			55	6	25P	2	6
		87	3	68	6	62P	1	74P	1	79	3	05P	1			56	4	23	2	9
81P	1	87	5	69	3	64P	1	75	2	80	3	22P	1	14	2	63	9	23	4	11
43		43		44		44		44		44		47		47		48		49		
14	3	2	6	4	5	8	8	6	9	4	2	18	4	1	1	16	5	2		

On the Mean Places and Proper Motions for 1900 *of* 24 *Southern Circumpolar Stars.* By David Gill, C.B., F.R.S., Her Majesty's Astronomer at the Cape.

The following are the results of a discussion of all known accurate fundamental determinations of the places of the circumpolar stars which are employed for azimuth-determination at the Cape Observatory.

The Cordoba places are the only not strictly fundamental results which are included in the discussion.

The Cape places employed depend almost entirely upon azimuths which have been determined by observations of very close circumpolars at one or more successive transits both above and below pole. In some few cases the Cape azimuths depend on the upper transits of several very close circumpolars combined with the lower transits of others, but such determinations have only been regarded as fundamental when the places of the azimuth-determining stars can be derived from fundamental observations made near the same epoch.

The unpublished Cape results, 1861–65, have been included in the discussion.

The only systematic corrections which have been applied are those required on account of the various systems of clock-stars employed.

The reductions to 1900 were computed by the rigorous trigonometrical formulæ, and the final mean place and proper motion for each star depends upon a least square discussion.

The whole of the observations, and especially the right ascensions, are very accurately represented. Details of the discussion will be published as an appendix to the Cape General Catalogue for 1890.

Star.	Mag.	R.A. 1900·0 h m s	P.M. in R.A. s	Dec. 1900·0. ° ′ ″	P.M. in Dec.
o Octantis	7·2	0 12 29·47	+0·006	−88 55 8·31	+0·001
Lacaille 634	5·6	1 43 7·85	+0·010	−85 16 29·14	+0·023
Lacaille 1029	7½	2 35 29·87	−0·018	−86 9 41·49	+0·001
Lacaille 1848	8·4	3 3 53·06	−0·052	−88 34 20·81	−0·030
Lacaille 1707	6·8	4 34 28·67	−0·018	−83 6 55·25	+0·015
Lacaille 2296	6·3	5 49 33·61	−0·010	−84 50 6·33	+0·086
Lacaille 2512	6·8	6 6 9·50	−0·022	−85 55 52·85	+0·004
Lacaille 3274	6·3	7 22 1·23	−0·009	−86 52 11·38	+0·007
A Octantis	7·8	7 53· 1·68	−0·028	−88 34 24·92	+0·010
ζ Octantis	5·5	9 11 14·16	−0·111	−85 15 46·81	+0·045
Lacaille 4510	6·9	10 36 55·09	−0·008	−85 34 21·32	−0·018
η Octantis	6·2	11 0 0·96	−0·056	−84 3 21·36	0·000
ι Octantis	5·4	12 44 26·89	+0·035	−84 34 48·60	+0·029
κ Octantis	5·7	13 24 42·05	−0·077	−85 16 24·74	−0·018
z Octantis	6·5	14 38 59·80	−0·186	−87 44 30·65	−0·061
ρ Octantis	5·7	15 20 11·44	+0·081	−84 7 55·04	+0·082
Lacaille 6545	6·0	16 23 34·41	−0·004	−86 10 42·67	+0·014
χ Octantis	5·2	17 56 4·34	−0·114	−87 39 51·38	−0·124
σ Octantis	5·5	18 59 43·21	+0·085	−89 15 16·45	−0·005
Lacaille 8094	6·3	19 37 36·44	−0·008	−81 36 0·52	+0·007
Lacaille 8257	7·1	20 18 47·39	+0·027	−84 44 48·45	+0·030
B Octantis	6·6	21 37 38·51	−0·012	−89 19 3·12	−0·034
C Octantis	5·7	22 12 34·98	−0·043	−86 28 33·63	+0·070
τ Octantis	5·6	23 13 9·48	+0·018	−88 1 52·85	+0·010

Royal Observatory, Cape of Good Hope:
1897 *April* 5.

New Double Stars found at the Cape Observatory in 1896.

(*Communicated by D. Gill, C.B., LL.D., &c., H.M. Astronomer.*)

The new double stars contained in the first of the two following lists have been found by Mr. R. T. A. Innes with the 7-inch equatorial of this observatory. They are numbered in continuation of his lists in the *Monthly Notices*, March 1895, vol. lv., and the *Journal of the B.A. Association*, April 1896, vol. vi. As the clock of the telescope is not sufficiently good for measuring, the angles and distances are estimated only. The second list contains stars found by the observers at the transit circle.

The magnitudes are taken from the different Cordoba determinations in nearly every case.

The mean date of observation may be taken as 1896·6.

No.	Star.	Mag.	1900. R.A. h	m	s	S.Dec. °	′	Estimated. p. °	Δ. ″	Mags.	Notes.
43	Lac. 9755	6·9	0	5	44	73	47·0	310	0·8	7·3– 8·3	Physical system. P.M. = 0″·13, 9°·1.
44	Lac. 95	7·6		23	27	55	10·6	250	0·75	7·9– 9·1	Lac. 102, mag. 7·3, is about 14′ N.f.
45	Lac. 130	6·9		28	49	55	52·8	280	0·8	7·1– 8·5	The chief star of *h* 3376, C being 10·5 mag. and 6′·5 distant.
46	Lac. 165	8·1		35	13	39	29·7	310	2 0	8·2–10·7	
47	Lac. 236	6·9		47	12	44	15·1	355	1·8	7·3– 8·1	
48	Lac. 272	7·2		54	0	67	6·0	342	0·75	7·5– 8·8	The P.M. is insensible
49	Lac. 278	7·0		56	17	53	7·3	40	0·8	7·5– 8·5	
50	C.Z. I. 293	9 0	1	12	42	37	48·4	140	1·0	9·4–10·4	Lac. 352, mag. 7·5, is 6 sec. f. 1½ N.
51	Lac. 460	7·0		30	6	46	12·4	15	1·4	7·2– 9·9	
52	C.Z. I. 1092	8·0		43	31	44	28·2	180	1 0	8·5– 9·5	The prec. of three stars in a curve.
53	Th−40°, 686	9·6	2	35	40	40	23·6	320	2·0	10·1–10·6	Closely N.p. C.Z. II. 953, mag. 8·3. Confirmed on Cape Cat. Plates.
54	C.Z. III. 123	8 7	3	5	0	41	44·7	320	0·7	9·4– 9·6	Closely S.f. Bris. 484, mag. 8·3.
55	P. III. 19	6·2		8	55	44	47·7	185	0·8	6·8– 7·3	This is the chief star of the old pair *h* 3556, the old companion being about 3″ distant and of mag. 10·4. When measuring this star in 1856 Jacob remarked "A suspicion that A is a close double in a direction nearly south." Likely to be an interesting system.
56	C.Z. III. 426	8·4		15	6	43	0·4	260	2·5	8·6–10·5	Bris. 553, mag. 7·6, is N.f.
57	C.Z. III. 686	9·0		24	0	59	38·2	210	1·5	9·2–10·4	C.G.A. 3804, mag. 8·7, is 12 sec. f.
58	χ_3 Fornacis	6·6		24	20	36	12·0	250	6·0	6·7–10·5	The central star of a group.

No.	Star.	Mag.	R.A. 1900. h m s	S.Dec. ° ′	Estimated. p. °	Δ. ″	Mags.	Notes.
59	P. IV. 92	6·7	4 21 14	34 58·9	210	60	...	A and B + C.
					265	3·0	9·5–10·5	B and C = C.P.D. − 35°, 482.
60	Cape 1880, No. 2025	8·7	38 6	45 53·8	270	2·0	9·4– 9·5	
61	Lac. 1805	7·8	5 15 14	41 8·8	100	0·9	8·2– 9·2	
62	C.Z. V. 972	8·0	27 48	47 16·5	175	1·0	8·4– 9·4	In a small group with Lac. 1888, mag. 5·7.
63	Lac. 2024	7·1	45 39	48 57·0	358	1·3	7·3– 9·3	A 10 mag. star S.f. 90″ ±.
64	P. V. 274	6·2	49 8	37 39·1	250	10·0	6·2–11·5	Another comes n.f. = 11 mag.
65	Lac. 2546	6·5	6 53 43	35 22·5	150	0·6	6·7– 8·2	In a group of four stars.
66	C.Z. VI. 2756	7·9	54 42	35 17·0	255	2	8·1– 9·6	In a group of four stars. C.Z. VI. 2754, mag. 9·5, is 15″ p.
67	B Velorum	5·4	8 19 27	48 10·2	145	1	5·6– 7·6	
68	C.Z. VIII. 2571	8·6	32 52	30 28·9	f.	4	8·8–10·3	
69	P. VIII. 148	6·2	36 39	39 54·5	n.f.	2	6·3– 9·0	
70	Lac. 3539	7·0	43 57	38 34·4	110°	1·5	7·2– 9·2	
71	Bris. 2285	7·5	53 44	49 17·7	n.p.	5	7·7– 9·2	The prec. of three stars.
72	I Velorum	5·8	9 23 2	52 56·7	p.	50	−9·0	A and B + C.
					...	3		B and C.
73	Lac. 4315	7·2	10 24 52	48 28·6	s.p.	3	7·2–10·0	Another comes 10·5 mag. N.f. 20″. C.Z. X. 1741, mag 7·8, is 8 sec. f. 3′ N.
74	Bris. 3103-4	8·5	31 33	63 36·7	s.p.	2	8·7–10·3	Lac. 4376, mag. 8·0, is about 30′ S. prec.

Day Age from Principal Minimum.		13				12				11		10		9		8		7			
		Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		Abs.	
		λ	f	λ	f	λ	f	λ	f	λ	f	λ	f	λ	f	λ	f	λ	f	λ	f
	d. h.	40		40		40		41		41		41		41		42		43		43	
8	7 7			26	5			02	8	21	2	30	4	45	4	33	2	36s	–	40	3
	7 8	–	–	26	3	–	–	02	10	22	2	30	4	45	2	s	–	36	–	40	4
	7 9	–	–	26	2	–	–	02	8	21	2	30	5	45	2			36s	–	40	4
	7 11	–	–	26	3	–	–	02	4	20	2	30	2	45	2	35	2	36s	–	40	3
	7 12	–	–	25	4	–	–	01	6	20	2	29	3	44	3	33	2	s	–	40	3
	7 15	–	–	25	4	–	–	01	10	22	2	30	4	44	4	35	3	36p	2	40	6
	7 18	21	–	26	3	97s	–	02	8	22	2	30	3	44	3	34	2	36	4	40	4
	7 21	22p	2	26	3	96p	2	01	4	21	2	30	3	44	2	34	2	36s	–	40	2
	7 23	–	–	27	4	98s	–	03	10	23	2	32	3	45	3	35	2	36	5	40	5
Means ...		22p	1	26	3	96p	1	02	8	21	2	30	3	45	3	34	2	36	4	40	4
9	8 8	–	–	26	4			02	8	20	2	30	3	45	3	35	2	35	2	40	4
	8 11	–	–	–	–	96s	–	01	4	20	2	30	2	43	2	33p	2	35p	2	40	5
	8 14	21s	–	25	4	96s	–	01	10	21	2	30	4	43	3	33	2	33	2	40	3
Means ...				26	4			01	7	20	2	30	3	44	3	34	2	34	2	40	4
10	9 3	–	–	26	4	s	–	01	6	20	2	29	3	43	2	s	–	34	2	40	4
	9 19	–	–	–	–	–	–	01	10	21	2	30	2	43	2	33	2	33	2	40	4
	9 20	20s	–	25	2	95s	–	01	10	19	2	30	3	44	3	34	2	33	5	40	6
	9 21	20s	–	26	4	95s	–	01	8	21	2	29	2	43	2	33	2	33	3	40	4
	9 21	20p	2	25	2	96s	–	01	10	21	2	30	3	44	3	33	2	34	3	40	5
	9 23	21s	–	27	3	94s	–	02	8	21	2	31	2	43	2	34	2	33	3	40	4
Means ...		20p	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	40	5
11	10 9	19s	–	25	4	94s	–	01	10	20	2	31	2	44	2	35p	2	33p	2	40	8
	10 18	19	2	24	4	94p	2	01	7	21	2	29	3	43	3	s	–	33p	2	40	4
	10 21	19s	–	25	4	96s	–	01	8	20	2	30	2	43	2			34	3	40	8
	10 22	21p	2	25	6	96s	–	01	8	20	2	30	2	44	2	33p	2	35	2	40	5
	10 23	–	–	–	–	–	–	03	6	21	2	30	2	44	2	s	–	34s	–	40	4
	10 23	–	–	25	3	–	–	03	10	22	2	31	2	45	2	34	2	36	2	40	7
Means ...		20p	2	25	4	94p	2	02	8	21	2	30	2	44	2	34p	2	34	2	40	6
		40		40		40		41		41		41		41		42		43		43	

s = suspected
Dash = inconclusive
} Excluded from means.

6			5			4			3			2		1	
Rad. λ	Rad. f	Abs. λ f	Rad. λ	Rad. f	Abs. λ f	Rad. λ	Rad. f	Abs. λ f	Rad. λ	Rad. f	Abs. λ f	Rad. λ	Rad. f	Abs. λ f	Date, &c. 1895.
13	43		44		44	44		44	47		47	48		49	m. d. h.
	87P	2	66	10		72	10	78 3	06	6		58	9	s –	6 11 11, g.
s –	87	2	66	10		73	10	78 3	09	6		58	10		6 11 12 „
s –	88	2	67	10		74	10	79 2	11	6		62	6		6 24 11, fair
	87	2	68	10		74	10	79 2	11	5		62	8		7 7 10–35, g.
	85	2	66	10		73	10	78 2	09	4		60	9		7 7 12, g.
	87	2	66	6		74	6	79 3	09	4	01P2	61	6		8 11 1 „
	87	2	67	9		74	9	79 3	12	5	05s–	62	8		9 10 8, v. g.
	87	2	65	8		73	8	79 2	12	4		60	10		9 23 9 „
81s–	88	2	66	10		73	10	80 2	13	6		62	9		10 19 7 „
	87	2	66	9		73	9	79 2	10	5		61	8		
s –	87	2	66	5		73	5	79 2	10	5		55	6		6 12 11¾, v. g.
81s–	86	2	64	5		73	5	78 3	11	4		55	4		6 25 13, poor
	86	2	66	3		73	3	78 2	06	4	00 2	58	4		7 21 12, fair
	86	2	65	4		73	4	78 2	09	4		56	5		
s –	87	1	62	2		71	2	77 2	06	3		50	5		5 18 11¼, g.
											46				
79s–	86	2	62	5		68	5	77 4	05	3	97P2	53	4		9 12 9, g.
80s–	86	2	62	4		70	4	78 2	06	3	98P2	54	10	s –	9 25 8, v. g.
79s–	86	2	61	5		69	5	78 2	05	5	97P2	53	10		9 12 11, g.
79s–	85	3	60	4		70	4	77 3	01	2	s –	55	6	24P2	9 25 9, v. g.
79s–	86	2	62	2		71	2	77 2	04	2		53	6		10 8 9, g.
	86	2	62	4		70	4	77 3	05	3		53	7	24P1	
79P2	87	4	63P	3	67s –	74s –		78s–	04s	–		54	6	– –	6 27 10½, v.g.
79P2	85	3	60	4	64 2	69	4	76 2	04	4	97s–	53	10	20P2	9 13 8 „
81s–	86	3	61	3	67P 2	73	3	78P2	05s	–		55	4	26P2	9 13 11 „
78s–	85	2	61	2	66 2	72	2	77 2				57	4	24s–	9 26 10, g.
s –	87	2	–	–	68s –	s	–	79 2	–	–		57	4	29P2	9 26 11 „
	86	3	62P	2	67 3	72P	2	78 3	05	3		54	5	23P2	10 22 7, v.g.
79P1	86	3	61	3	66 2	72	3	78 2	05	2		55	6	25P2	
43	43		44		44	44		44	47		46	48		49	

P = probable.
Blank = no line.

Day Age from Principal Minimum.		13				12				11		10		9		8		7			
		Rad.		Abs.		Rad.		Abs.		Abs.		Abs.		Abs.		Abs.		Rad.		Abs.	
		λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι	λ	ι
		40		40		41		41		41		41		41		42		43		43	
12	11 8			26	6			01	10	22	2	30	4	44	4	34	2	35s	–	40	6
	11 8	21s	–	26	4	96s	–	01	8	22	2	30	3	45	3	34	2	35P	2	40	5
	11 9			26	4			01	8	20	3	30	4	45	3	–	–	s	–	40	5
	11 9			26	4			01	10	20	2	29	3	43	3	33	2	31	2	40	5
	11 19			25	3			01	7	20	2	30	2	44	2	33s	–			40	4
	11 20			26	4	94P	2	01	6	20	2	30	2	43	2	s	–			40	3
	11 21	20s	–	26	4	s	–	02	7	21	2	30	2	45	3	33	2			40	5
	11 21	21P	2	25	5	s	–	01	10	20	2	30	3	44	3	33	2			40	4
	11 23			26	3			02	6	21	2	31	3	44	3	s	–	35P	2	40	4
Means ...				26	4			01	8	21	2	30	3	44	3	33	2	34P	1	40	5
13	12 7			25	7			01	10	20	2	30	4	43	4	33	2	34s	–	40	4
	12 8			25	7			02	10	22	2	30	4	45	4	34	2	s	–	40	5
	12 10			26	5			02	8	21	2	30	3	44	3	33	2	34P	2	40	3
	12 11			25	4			02	6	22	2	31	3	44	3	34	2	s	–	40	2
	12 12			25	4			02	6	21	2	30	4	45	3	34	2	s	–	40	2
	12 14	18s	–	26	6	95s	–	01	10	21	2	30	4	45	4	35	3	35P	2	40	5
	12 17	s	–	26	8	s	–	02	8	22	2	30	3	45	4	34	2			40	2
	12 19			26	5			02	6	22	2	31	3	45	3	s	–			40	2
	12 20			26	5			01	6	22	2	30	2	44	2	33	2			40	2
	12 21			27	6			02	6	22	2	32	3	45	3	35	1			40	3
	0 0			26	6			02	6	21	2	30	3	46	4	35	2			40	3
Means ...				26	6			02	7	21	2	30	3	45	3	34	2	35P	1	30	3
		40		40		41		41		41		41		41		42		43		43	

s = suspected
Dash = inconclusive } Excluded from means.

6				5				4				3				2		1		
Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Rad.		Abs.		Date, &c. 1895.
λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	λ	i	
3		43			44	44		44		44		47		46		48		49		m. d. h.
		87	3	–	–	68	4	s	–	78	3	s	–	s	–	55	2	24	2	6 15 12, g.
31	P2	86	4	63P	2	69	4	74P	2	79	2			s	–	54	4	24	P2	6 15 11½ ,,
s	–	87	3			68	4			80	3	04P	2	96	P2	57	2			6 15 12¾ ,,
		87	3	–	–	66	2	s	–	78	2	05P	2			53	3	s	–	6 15 13¼, v.g.
		86	3			69	4			80	3	07s	–	99s	–	62s	–			9 27 7, g.
s	–	87	3	60P	2	68	7			79	3					60	4	21	PI	9 27 8 ,,
		87	4			69	8			79	4					58	5	21	4	9 27 9, v.g.
		86	4			68	8			79	4	s	–	s	–	55	5	20s	–	10 10 7, g.
80s	–	86	3	62P	2	67	10	74P	2	78	3	04s	–	97s– 47 09s–		54	3	23	2	10 23 7, v.g.
		87	3	62P	1	68	6	74P	1	79	3	05P	1			56	4	23	2	
79s	–	85	4	63P	2	68	3	74P	2	78	3			–	–	58	9	21	4	6 16 10½, v.g.
s	–	87	5			69	3			80	3	21P	2	s	–	60	6	21	4	6 16 11½ ,,
s	–	87	4	s	–	68	3	s	–	79	3	22P	2	s	–	60	4	23	3	7 12 10-25, v.g.
		87	3	s	–	68	3	s	–	79	3					61	9	21	4	7 12 10-40, g.
		87	5	s	–	68	2	74P	2	79	2	s	–			60	10	24	3	7 12 11-40, v.g.
82	P2	87	5	64P	2	69	5	75P	2	79	5	s	–	13	3	64	9	24	4	8 7 10, v.g.
		89	6			70	3			81	3	s	–	15	2	65	10	24	4	9 2 9, g.
81	P2	88	6	64s	–	70	3	76P	2	81	3			13	2	65	10	24	4	9 15 8¾, v.g.
81	P2	87	5	–	–	68	3	74	4	79	3	18s	–	13	2	64	10	20	2	9 15 10, poor.
		89	4	64P	2	70	3	76	4	80	3			13	3	65	10	24	3	9 15 11-15, v.g.
		88	5			69	4	75	6	80	4			15	1	68	10	23	4	9 15 11¾ ,,
81	PI	87	5	64P	1	69	3	75	2	80	3	22P	1	14	2	63	9	23	4	
43		43		44		44		44		44		47		47		48		49		

P = probable.
Blank = no line.

Spectrum of β Lyræ, 1895, *Stonyhurst College Observatory.* ***Mean***

	13				12				11		10		9		8		7			
Day of Age.	Rad. λ	Rad. i	Abs. λ	Abs. i	Rad. λ	Rad. i	Abs. λ	Abs. i	Abs. λ	Abs. i	Abs. λ	Abs. i	Abs. λ	Abs. i	Abs. λ	Abs. i	Rad. λ	Rad. i	Abs. λ	Abs. i
	40		40		41		41		41		41		41		42		43		43	
1	29	1	26	7	05P	1	02	7	21	3	30	4	44	5	35	3	46	5	40	5
2	29P	2	26	8	05P	2	01	10	21	2	30	4	44	4	34	2	45	7	40	10
3	29P	2	26	6	06P	2	01	10	20	2	30	3	44	3	34	2	45	9	40	7
4	30	5	25	5	06	4	01	10	20	2	30	3	43	3	35	2	46	8	40	8
5	30P	2	26	5	06	3	01	9	20	2	30	3	44	3			47	8	40	6
6	29P	1	26	4			02	9	21	2	30	3	44	3	34	2	46	6	40	4
7	30P	1	26	3			02	6	21	2	30	3	44	3	34	2	46	3	40	3
8	22P	1	26	3	40 96P	1	02	8	21	2	30	3	45	3	34	2	36	4	40	4
9			26	4			01	7	20	2	30	3	44	3	34	2	34	2	40	4
10	20P	2	26	3			01	9	21	2	30	3	43	2	33	2	33	3	40	5
11	20P	2	25	4	94P	2	02	8	21	2	30	2	44	2	34P	2	34	2	40	6
12			26	4			01	8	21	2	30	3	44	3	33	2	34P	1	40	5
13			26	6			02	7	21	2	30	3	45	3	34	2	35P	1	40	3
	40		40		40		41		41		41		41		42		43		43	
Range	10	4	1	5	12	3	1	4	1	1	0	2	2	3	2	1	14	8	0	7

Wave-lengths and Intensities of the Selected Groups for each Day Age.

6				5				4				3				2		1		
Rad. λ	Rad. i	Abs. λ	Abs. i	Abs. λ	Abs. i	Rad. λ	Rad. i	Rad. λ	Rad. i	Abs. λ	Abs. i	Rad. λ	Rad. i	Abs. λ	Abs. i	Rad. λ	Rad. i	Abs. λ	Abs. i	No. of Plates
43		43		44		44		44		44		47		47		48		49		
93P	1	88	8	70	7			76	7	81	4	21	1	13	3	68	9	25	4	6
93	3	88	6	70	6			76	9	79	3	20	2	14	3	69	5	25	3	9
92P	2	87	3	70	3			75	9	78P	2	18	4			69	6	23	2	7
93	3	87	3	70	2			75	9	79	2	19	3			70	6	24	2	7
92	4	86	3					76	9			16	5			68	8			4
93	3	88	2			69	7	74	10	80	2	17	5			67	7			5
92	1	87	2			69	9	74	10	79	2	15	4			66	6			6
		87	2			66	9	73	9	79	2	10	5			61	8			9
		86	2			65	4	73	4	78	2	09	4			56	5			4
		86	2			62	4	70	4	77	3	05	3			53	7	24P	1	5
79P	1	86	3	66	2	61	3	72	3	78	2	05	2			55	6	25P	2	6
		87	3	68	6	62P	1	74P	1	79	3	05P	1			56	4	23	2	9
81P	1	87	5	69	3	64P	1	75	2	80	3	22P	1	14	2	63	9	23	4	11
43		43		44		44		44		44		47		47		48		49		
14	3	2	6	4	5	8	8	6	9	4	2	18	4	1	1	16	5	2		

cluster, the definition on the whole was very satisfactory, and the resulting measures will not, I think, be affected by any considerable errors.

The whole region has been very carefully examined, and all objects measured which seemed to possess any real interest. The objects are arranged and numbered in order of right ascension, and wherever possible, I have given the corresponding numbers in Gould's very accurate catalogue of this cluster (G). The positions of the stars are referred to the equator and mean equinox of 1900·0.

No. 1 = G 10.

$\alpha = 10^h\ 36^m\ 46^s{\cdot}0$; $\delta = -59°\ 1'\ 19''{\cdot}0$.

8·2, yellow; 11·6, bluish yellow.

t	θ.	ρ.		
1897·181	274°·1	17″·42	seeing 5	

No. 2 = H_2 4347.

$\alpha = 10^h\ 38^m\ 19^s{\cdot}0$; $\delta = -59°\ 22'\ 59''{\cdot}0$.

10, yellow; 11·7, bluish yellow.

1897·178	303°·2	3″·35	seeing 5	close system.
1897·179	304·6	3·54	5	
1897·181	307·1	2·42	5	
1897·184	...	3·25	5	
1897·180	305·0	3·14		

No. 3. Triple.

$\alpha = 10^h\ 38^m\ 21^s{\cdot}5$; $\delta = -59°\ 26'\ 35''{\cdot}7$.

10·4, yellow; 11·7, yellow; 12·9, bluish yellow.

AB. New.

1897·181	349°·2	2″·88	seeing 5	
1897·182	348·3	3·12	5	
1897·184	347·1	2·74	5	
1897·185	345·2	3·44	5	
1897·183	347·5	3·05		

AC = H_2 4348.

1897·181	259°·3	13″·84	seeing 5	
1897·182	259·9	13·89	5	
1897·184	259·6	14·24	5	
1897·185	259·5	14·03	5	
1897·183	259·6	14·00		

No. 4 = H_2 4354.

$\alpha = 10^h\ 39^m\ 57^s{\cdot}2$; $\delta = -59°\ 34'\ 20''{\cdot}9$.

10·6, yellow; 12·6, bluish.

	1897·175	218°·4	10″·25	seeing 5
	1897·176	216·9	10·42	5
	1897·178	216·9	10·49	5
	1897·176	217·4	10·39	
Herschel	1836·471	228·4	12	1s

No. 5 = G 78.

$\alpha = 10^h\ 40^m\ 3^s{\cdot}0$; $\delta = -59°\ 1'\ 32''{\cdot}1$.

8·5, yellow; 12·4, bluish yellow.

	1897·181	236°·7	7″·27	seeing 5
	1897·182	237·0	6·76	5
	1897·184	240·7	7·85	5
	1897·185	241·7	7·40	5
	1897·183	239·0	7·32	

No. 6 = G 80 = H_2 4356.

$\alpha = 10^h\ 40^m\ 5^s{\cdot}8$; $\delta = -59°\ 1'\ 21''{\cdot}2$.

7·5, orange yellow; 11·9, bluish purple.

	1897·175	151°·6	2″·75	seeing 6	Physical system
	1897·176	149·6	2·74	6	
	1897·178	147·4	3·07	5	
	1897·181	147·9	2·76	5	
	1897·178	149·1	2·83		
				Mags.	
Herschel	1836·463	150°·5	2″	7·5 ; 9	
	1837·312	147·3	2	8 ; 11	

No. 7 = G 82 = H_2 4359.

$\alpha = 10^h\ 40^m\ 7^s{\cdot}6$; $\delta = -59°\ 34'\ 0''{\cdot}8$.

10·4, yellow; 12 6, bluish.

	1897·175	234°·6	6″·74	seeing 5
	1897·176	234·8	6·66	5
	1897·178	232·8	6·52	5
	1897·176	234·1	6·64	
Herschel	1837·309	238·6	6	1s

No. 8 = G 83. New.

$\alpha = 10^h\ 40^m\ 8^s.3$; $\delta = -59°\ 0'\ 57''.4$.

9·4, yellow: 13, bluish yellow.

1897·175	306°8	4″17	seeing 5
1897·176	307·2	4·11	5
1897·178	305·4	3·55	5
1897·181	303·1	3·37	5
1897·177	305·6	3·80	

No. 9 = H_2 4358.

$\alpha = 10^h\ 40^m\ 10^s.6$; $\delta = -59°\ 34'\ 31''.6$.

10·4, yellow; 12·7, bluish.

1897·175	192°3	8″36	seeing 5
1897·176	192·7	7·95	5
1897·178	194·2	8·04	4
1897·176	193·1	8·12	
Herschel 1837·309	199·4	8	In

No. 10 = ZC 2864 = H_2 4360. Triple.

$\alpha = 10^h\ 40^m\ 15^s.5$; $\delta = -59°\ 3'\ 1''.8$.

A = 8·3, yellow; 9·0, yellow; 9·3, yellow.

BC.

1897·175	118°2	1″67	seeing 5
1897·176	120·8	1·84	6
1897·178	118·0	1·84	4
1897·176	119·0	1·78	
Herschel 1837·309	111·3	1	In

$\frac{BC}{2}$ and A = B 3190.

1897·175	108°6	14″27	seeing 5
1897·176	108·2	14·29	6
1897·178	108·3	13·91	4
1897·176	108·4	14·16	
Herschel 1834·197	102·7	15	
1837·309	106·8	12	

No. 11 = G 107 = B 3194.

$\alpha = 10^h\ 40^m\ 42^s{\cdot}1$; $\delta = -59°\ 12'\ 45''{\cdot}8$.

9, yellow ; 9·2, yellow.

1897·181	213°·7	18″·81	seeing 5
1897·182	214·0	18·64	5
1897·182	213·8	18·72	

There is a small double n.p. this system, 90° ±, 3″·8 ± mags. 12·5 ; 13, both yellow.

Herschel	1834·197	206°·1	12″	1*n*

No. 12 = A.G.C. 14715 = H_2 4364. Triple.

$\alpha = 10^h\ 40^m\ 51^s{\cdot}4$; $\delta = -58°\ 50'\ 3''{\cdot}0$.

8·9, yellow ; 10·1, yellow ; 11·1, yellow.

AB.

1897·175	354°·6	8″·27	seeing 5
1897·178	355·5	7·92	5
1897·176	355·1	8·09	

AC.

1897·175	147°·4	[8″·27 ±]	seeing 5
1897·178	148·1	9·46	5
1897·181	146·8	9·47	5
1897·178	147·4	9·46	

No. 13, system n.f. η *Carinæ* = H_2 4366.

$\alpha = 10^h\ 41^m\ 11^s{\cdot}4$; $\delta = -59°\ 9'\ 32''{\cdot}7$.

11·4, bluish yellow ; 12·8, bluish yellow.

1897·175	141°·0	5″·28	seeing 5
1897·176	141·2	5·40	5
1897·178	144·5	[4·47]	5
1897·181	143·9	5·19	5
1897·182	143·2	5·51	5
1897·178	142·8	5·35	

A and η *Carinæ* (H_2 4366, No. 2).

	1897·175	37°·7	13″·82	seeing 5
	1897·178	41·6	14·33	5
	1897·181	38·9	14·30	5
	1897·178	39·4	14·15	
Herschel	1834·197	30·3	15	A and η *Carinæ*.
	1834·197	46·8	12	B and η *Carinæ*.

No. 14 = ZC 2946.

$\alpha = 10^h\ 41^m\ 20^s{\cdot}1$; $\delta = -59°\ 13'\ 30''{\cdot}0$.

9, yellow; 9·5, yellow.

1897·192	190°·3	16′·12	seeing 3	Hazy.
1897·193	190·9	15·75	3	
1897·192	190·6	15·94		

No. 15 = A.G.C. 14744 = H_2 4369.

$\alpha = 10^h\ 41^m\ 57^s{\cdot}1$; $\delta = -58°\ 57'\ 45''{\cdot}2$.

7·3, reddish; 12·1, bluish purple.

1897·175	40°·7	14″·60	seeing 5
1897·178	41·4	14·96	4
1897·179	41·3	14·92	4
1897·177	41·1	14·83	

No. 16 = G 166.

$\alpha = 10^h\ 43^m\ 23^s{\cdot}2$; $\delta = -59°\ 34'\ 1''{\cdot}4$.

8·5, yellow; 11·5, bluish.

1897·181	115°·5	16″·78	seeing 5

Faint system n.f. at dist. of 25″ ±.

1897·181	274°·6	8′·28	seeing 5

Magnitudes 10·5, 11·5, both yellow.

No. 17 = G 190 = H_2 4374.

$\alpha = 10^h\ 44^m\ 58^s{\cdot}8$; $\delta = -58°\ 55'\ 6''{\cdot}4$.

9·4, yellow; 12·8, bluish yellow.

1897·192	117°·5	14″·89	seeing 4	Hazy.
1897·193	117·3	14·52	3	
1897·192	117·4	14·71		

No. 18 = ZC 3447 = A.G.C. 14880.

$\alpha = 10^h\ 48^m\ 21^s{\cdot}8$; $\delta = -58°\ 12'\ 56''{\cdot}9$.

9, yellow; 12·5, bluish.

1897·192	217°·9	3″·89		blurred, hazy.
1897·193	218·3	3·29	seeing 3	
1897·192	218·1	3·59		

Although the above comparison does not indicate any very large or certain motion in the double stars of this group, I think it probable that some of the apparent changes are real. If some of the systems should be found to be in motion the result would ultimately possess a high value, as throwing light upon the connection of the stars of this cluster with the nebula in which they are projected. The region is remarkably rich in fairly close double stars, and one would naturally think that some of them at least are physical systems; but it may require ages for their motions to develope.

It had been my intention to make a very careful drawing of this great nebula, but it now seems best to defer the execution of the plan till a more convenient location of the observatory further south shall furnish more favourable conditions for a faithful delineation of its many delicate and wonderful details. It seems proper to add that when viewed with the 24-inch refractor the striking phenomena disclosed have no close resemblance to the drawings executed by Sir John Herschel, nor to the photographs recently secured by Dr. Gill. The greatly increased detail shown renders the appearance one of great complexity, and hence a really authoritative sketch will require the most favourable conditions, besides the exercise of much skill and care.

Lowell Observatory, City of Mexico:
1897 *March* 15.

The Orbit of μ Draconis. By S. W. Burnham.

As a double star this is known as Σ 2130 (= Ḫ II. 13 = Sh 242). It was discovered by Herschel I. 1779 October 17, and, as the distance was between 4″ and 8″, it was placed in his Class II. Both angle and distance were measured, and the latter recorded as 4″·354 "mean measure" (*Phil. Trans.* 1782). In his "Synopsis" of his father's double-star observations (*Mem. R.A.S.* vol. xxxv.) Herschel II. gives this distance as 4″·69, and the date a few days later than that in the original publication, and the date of the measure of the position angle as 1781·73. The latter

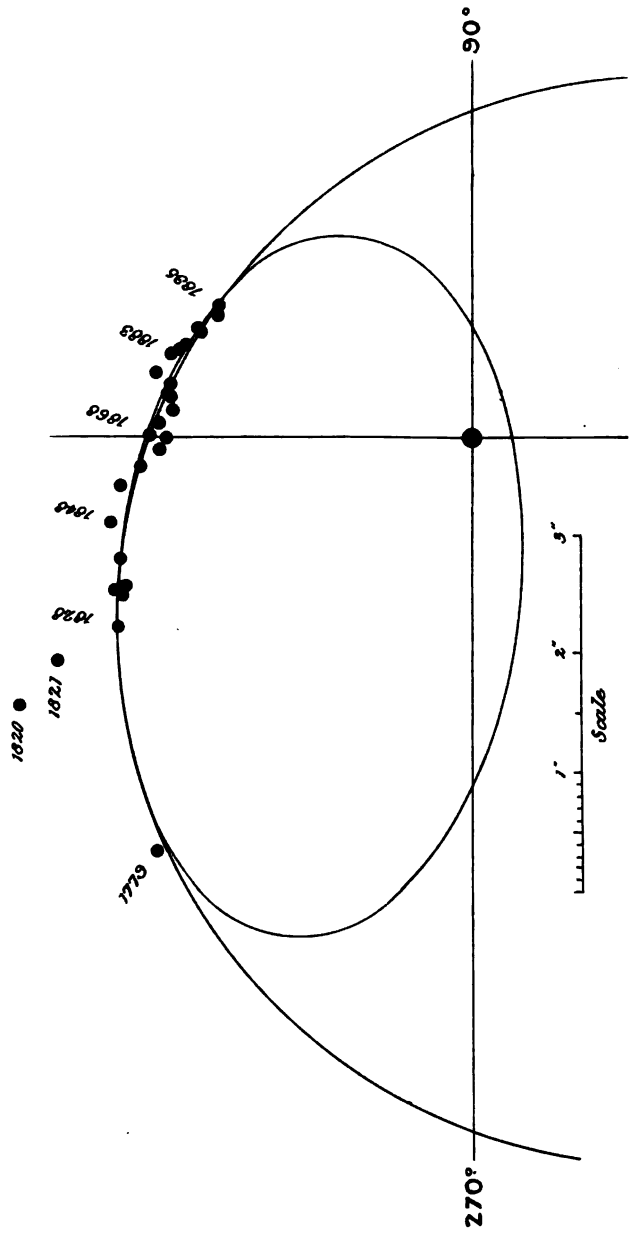
would seem to be a mistake, since Herschel I. has only the single observation of 1779 October 19 in his first catalogue above referred to. There may be some warrant for this in the original MS., and for increasing the distance to 4″·69 ; but the smaller distance value is used in Herschel and South's Catalogue of 1824, and in the early measures of Dawes and other observers. I have used here the original values of both distance and epoch.

In 1804 Herschel recognised the angular motion, and said, "The stars being of nearly equal magnitude, we can have no inducement to suppose them to be at very different distances from us." Struve made measures of it in 1819 and 1821 before the commencement of the work recorded in *Mensuræ Micrometricæ*, and South and Herschel have a single observation in 1821. After citing the previous measures, the latter observers say : "No doubt, therefore, can remain of the reality of an angular motion in this star, as announced by Sir William Herschel in 1804 ; and the observations here brought together prove it to have been hitherto nearly uniform, and averaging 0°·579 per annum in the direction *npsf*, or retrograde. There can be little doubt of its being a binary system—a miniature of *a Geminorum*."

Systematic work on this star was commenced by Struve in 1828, and since that time there is no lack of carefully made reliable mean results from measures on different nights down to the present time. The retrograde motion recognised by the early observers has steadily continued, accompanied with a slow diminution in the distance. According to Struve, the magnitudes of the components are 5·0 and 5·1.

On the accompanying diagram (Plate 18), I have given a careful selection of the best measures by the principal observers for the last hundred years. The following dates and observers are represented by complete measures of angle and distance :—

1781	1*n* ♄	1872	7*n* De
1820	2*n* Σ	1875	7*n* Du
1821	1*n* Sh	1876	3*n* Jed
1828–36 (4)	13*n* Σ	1877	8*n* Hall
1840	6*n* Da	1879	3*n* Jed
1848	1*n* Da	1883	10*n* Per, En, Jed
1855	15*n* De	1885	7*n* Hall, Per, Jed
1858	3*n* De	1886	3*n* Jed
1863	7*n* De	1888	3*n* Maw
1866	6*n* De	1889	10*n* β, Hall, Maw
1868	3*n* Du	1893	7*n* Leavenworth, Comstock
1871	11*n* OΣ, Du	1895	10*n* See, Collins, Comstock



Orbit of μ Draconis.

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It is evident that the distances in the early measures of Struve, and Herschel and South, 1819 to 1821, are too large, or that the distance in 1781 is too small. The later measures of Struve appear to show that his previous measures of distance were much too large, and he seems to have considered them as not very reliable, since they are not mentioned in *Mensuræ Micrometricæ.*

One orbit has been computed for this system. Berberich (*Astr. Nach.* 2582), from an examination of the measures down to 1883, found a period of 648·0 years. As in all double stars as wide as this, and as easy of measurement, where the observed arc is short, the various measured positions are well represented by the apparent orbit; and, so far as the agreement between the observed and computed places is concerned, there is nothing for unfavourable criticism; but it is obvious enough from even a casual inspection of the diagram that the data are altogether insufficient for even the roughest approximation to the apparent ellipse and the elements of the real orbit. Indeed, as might be expected, the measures since 1883 are steadily leaving the computed positions. The chances are that the relative change will finally resolve itself into orbital motion; but, judging from the motion in the last hundred years, it will be a very long time before anything more than the bare fact of physical connection can be established, to say nothing about the details of that relation.

Doberck gives formulæ for the angles and distances (*Trans. R.I. Acad.* vol. xxvi.), and a comparison of the positions thus found with some of the measures from 1781 to 1875. For this interval the theory holds fairly well, but the measures since that time are not so well represented.

By way of showing how easily these positions are represented by orbits wholly unlike in all respects, I have given on the diagram two of the many which could be found. So far as the observed arc is concerned, these figures are practically identical, and represent all the measures down to 1883 as well as, if not better than, the computed orbit, and the six later positions are much better represented. Herschel's distance is practically perfect, and the angle requires a correction of only 2°·8, which is much less than the probable error of measures made in the last century. The ellipse with a major axis of 5″·88 gives a period of about 280 years, and the circle with a diameter of 9″·16 a period of 1,190 years, the eccentricity in the one case being 0·84, and zero in the other. Of course an almost infinite variety of conic sections could be shown which would be equally satisfactory, so far as the measures are concerned.

In 1889, with the 36-inch refractor of the Lick Observatory, I detected a third star (β 1088), exceedingly faint, at a distance of about 12″ from B. Four sets of measures have been made of this star since that time—the last in 1895—and they appear to indicate that this minute companion has the same proper motion

as the bright stars. These measures have the following differences from the mean :—

1889·27	−0°·2	−0″·02	3*n* β
1891·30	+1·0	+0·03	3*n* β
1892·36	−0·6	+0·12	3*n* β
1895·28	−0·1	−0·13	3*n* B

These measures were all made with the 36-inch refractor, the last by Barnard in 1895. If the small star is stationary, the proper motion of the large star during the interval covered by the measures would increase the distance of C about 0″·4, and make the angle 3° less, and such a change one would expect to appear in the measures. The close agreement of the measures renders it improbable that any such change has taken place. However, the new star is a faint object even with the large aperture, and a longer interval may be necessary to establish with certainty the fact of common proper motion.

Cometary Observations at the Liverpool Observatory, 1896. By W. E. Plummer, M.A.

This paper is practically a continuation of that given in the June number of the *Monthly Notices* of last year, and the remarks there made apply equally to the observations here given. The instrument and the micrometers employed, as well as the method of reduction pursued, are precisely the same as those mentioned in the earlier paper. The abbreviations given in the column headed 'No. of Comparisons' are also explained in that place. The comets have mostly been faint objects, and the use of the filar micrometer has generally been impossible. In the case of Swift's Comet of last April the approximate sub-polo position did not permit the instrument to be reversed, so that any error in the orientation of the micrometer has a very injurious effect. On some occasions portions of the object-glass were cut off by the mounting of the instrument.

Comet 1896 *I.* (*Perrine-Lamp*).

Greenwich Mean Time of Observation.				✐−✱R.A.	No. of Comparisons (a)	Apparent R.A. of Comet.			✐−✱ Declination.	No of Comparisons (δ)	Apparent Declination of Comet.			Log. Factor of Parallax in (a)	Log. Factor of Parallax in (δ)	Letter of Reference.
		h	m	s		h	m	s	′	″	°	′	″			
1896 Feb.	22	16	22	57·2	+ 52·15	25	21	0	57·78	+ 3 18·7	5	+27	56	42·6	−9·5945	0·8245	*a*
	22	16	22	57·2	+2 35·28	25	21	0	57·65	+ 2 11·3	5	+27	56	43·2	−9·5945	0·8245	*b*
	23	16	30	16·0	+2 1·89	25	21	22	10·50	+ 4 23·9	5	+32	34	48·7	−9·6112	0·8179	*c*
Mar.	1	7	26	45·4	−2 34·08	Ret.	0	18	6·84	+ 8 10·7	Ret.	+50	50	35·2	+9·7448	0·6072	*d*
	1	7	26	45·4	−1 35·90	,,	0	18	5·31	− 9 12·1	,,	+50	50	37·0	+9·7448	0·6072	*e*
	3	9	0	34·6	+1 24·00	20	1	5	44·60	+10 9·7	5	+51	44	54·4	+9·7515	0·6934	*f*
	4	10	40	10·0	−1 36·46	15	1	26	41·36	+ 7 13·8	4	+51	44	43·0	+9·6995	0·8034	*g*
	4	10	40	10·0	−2 24·66	15	1	26	41·85	+ 6 29·1	4	+51	44	37·7	+9·6995	0·8034	*h*
	9	9	16	3·7	−1 15·68	Ret.	2	35	13·59	+ 4 0·3	Ret.	+50	0	48·7	+9·7387	0·6192	*i*
	9	9	16	3·7	− 20·87	,,	2	35	13·67	− 38·0	,,	+50	0	48·3	+9·7387	0·6192	*j*

Greenwich Mean Time of Observation.				☄−✱R.A.	No of Comparisons (α)	Apparent R.A. of Comet.			☄−✱ Declination.	No. of Comparisons (δ)	Apparent Declination of Comet.			Log. Factor of Parallax in (α)	Log. Factor of Parallax in (δ)	Letter of Reference.
	h	m	s	s		h	m	s	″		°	′	″			
1896 Mar. 11	9	10	50·2	+2 8·19	Ret.	2	53	24·72	− 4 49·6	Ret.	+49	4	42·6	+9·7259	0·6051	*k*
11	9	10	50·2	+1 39·94	,,	2	53	24·80	− 1 0·1	,,	+49	4	40·9	+9·7259	0·6051	*l*
16	9	28	42·5	−1 22·62	,,	3	25	34·97	− 1 54·0	,,	+46	53	52·4	+9·7091	0·6376	*m*
19	10	2	11·3	+1 44·57	,,	3	39	8·15	+ 25·0	,,	+45	46	55·9	+9·7038	0·6966	*n*
21	8	53	11·4	− 18·06	,,	3	46	24·60	− 3 54·2	,,	+45	8	30·7	+9·6801	0·6035	*o*
Comet 1896 *III.* (*Swift*).																
Apr. 21	9	1	13·7	+1 51·18	Ret.	3	32	53·80	+ 9 24·9	Ret.	+30	56	7·2	+9·5886	0·8431	*a*
22	8	53	30·0	−1 31·92	25	3	30	48·03	+ 3 50·5	5	+33	34	59·8	+9·6023	0·8302	*b*
23	9	10	5·2	+3 12·32	20	3	28	19·37	+ 5 12·8	5	+36	13	4·9	+9·5986	0·8459	*c*
24	9	14	16·1	+1 10·11	25	3	25	30·73	− 2 1·9	6	+38	45	39·0	+9·6033	0·8478	*d*
24	9	14	16·1	−1 41·94	25	3	25	30·69	−11 52·1	6	+38	45	37·6	+9·6033	0·8478	*e*
28	9	26	35·3	+1 21·05	25	3	10	42·01	+ 3 4·1	5	+47	56	58·5	+9·6166	0·8553	*f*
28	9	26	35·3	+1 4·95	25	3	10	41·99	+12 8·7	5	+47	56	59·3	+9·6166	0·8553	*g*
29	10	3	52·9	+ 16·44	Ret.	3	6	1·95	− 3 32·0	Ret.	+50	0	34·4	+9·5497	0·8829	*h*
29	10	3	52·9	− 38·57	,,	3	6	2·17	+ 0 58·8	,,	+50	0	32·5	+9·5497	0·8829	*i*
May 1	10	16	40·0	−3 47·83	19	2	55	57·82	− 2 33·8	4	+53	40	14·3	+9·5066	0·8909	*j*
1	10	16	40·0	−3 54·00	19	2	55	57·92	− 2 29·4	4	+53	40	11·2	+9·5066	0·8909	*k*
3	11	9	37·1	−1 46·69	25	2	44	35·29	− 51·5	5	+56	53	42·5	+9·2079	0·9112	*l*
3	11	9	37·1	− 11·91	25	2	44	35·26	+ 3 54·2	5	+56	53	40·9	+9·2079	0·9112	*m*
4	10	13	30·4	+6 26·26	Ret.	2	38	50·70	+ 2 37·3	Ret.	+58	15	22·5	+9·5395	0·8792	*n*

Greenwich Mean Time of Observation.					✱−★ R.A.	No. of Comparisons (α)	Apparent R.A. of Comet.			✱−★ Declination.	No. of Comparisons (δ)	Apparent Declination of Comet.			Log. Factor of Parallax in (α)	Log. Factor of Parallax in (δ)	Letter of Reference.
		h	m	s	s		h	m	s	′ ″		° ′ ″					
1896 May	4	10	13	30·4	−1 42·83	Ret.	2	38	51·06	− 8 26·3	Ret.	+58 15 25·7			+9·5395	0·8792	*o*
	5	10	29	59·7	+2 58·80	20	2	32	35·70	− 3 28·4	5	+59 34 44·0			+9·3652	0·8966	*p*
	6	9	49	50·5	−1 15·42	,,	2	26	24·38	+ 6 10·7	,,	+60 45 23·1			+9·5149	0·8789	*q*
	6	9	49	50·5	−1 31·87	,,	2	26	25·02	− 13·2	,,	+60 45 25·7			+9·5149	0·8789	*r*
	7	11	0	11·2	+2 33·90	25, Ret.	2	19	32·24	− 4 41·1	5, Ret.	+61 55 28·7			+8·9375	0·9011	*s*
	7	11	0	11·2	− 51·53	,,	2	19	31·57	+10 23·1	,,	+61 55 27·2			+8·9375	0·9011	*t*
	8	10	36	40·3	+ 17·02	Ret.	2	12	56·64	+ 3 32·1	Ret.	+62 55 58·0			+9·1248	0·8955	*u*
	8	10	36	40·3	+4 50·34	,,	2	12	56·39	+10 51·0	,,	+62 55 57·1			+9·1248	0·8955	*v*
	9	10	20	32·2	−4 33·35	,,	2	6	10·97	− 4 43·5	,,	+63 51 55·0			+9·1943	0·8904	*w*
	9	10	20	32·2	−6 1·21	,,	2	6	10·72	+ 23·0	,,	+63 51 52·5			+9·1943	0·8904	*x*
	10	10	44	0·1	−1 44·39	,,	1	59	7·07	+12 4·9	,,	+64 44 40·4			+8·6180	0·8916	*y*
	10	10	44	0·1	+2 16·94	,,	1	59	6·13	+ 8 25·1	,,	+64 44 42·0			+8·6180	0·8916	*z*
	11	11	3	50·0	+5 36·34	,,	1	51	58·34	− 6 59·3	,,	+65 33 6·2			−8·8789	0·8877	*aa*
	12	11	56	29·4	+3 15·69	,,	1	44	36·87	+ 2 0·5	,,	+66 18 2·9			−9·4995	0·8668	*bb*
	12	11	56	29·4	− 8·83	,,	1	44	37·15	+ 4 44·6	,,	+66 18 4·5			−9·4995	0·8668	*cc*
	13	11	45	16·3	−2 46·73	,,	1	37	29·41	+16 25·1	,,	+66 57 34·0			−9·5108	0·8637	*dd*
	16	10	40	26·0	+3 18·19	,,	1	16	6·95	+ 3 43·1	,,	+68 36 50·2			−9·3419	0·8677	*ee*
	19	11	2	3·1	−0 21·09	,,	0	54	17·60	− 2 47·0	,,	+69 54 48·3			−9·6976	0·8360	*ff*
	19	11	2	3·1	+2 57·48	,,	0	54	16·92	− 1 11·0	,,	+69 54 47·0			−9·6976	0·8360	*gg*
June	2	11	35	50·4	+0 15·98	,,	23	16	8·89	− 1 12·7	,,	+72 42 47·1			−0·0568	0·5591	*hh*

Comet I. 1897 (*Perrine*, 1896 *November* 2).

Greenwich Mean Time of Observation.				♂−✳ R.A.	No of Comparisons (α)	Apparent R.A. of Comet.			♂−✳ Declination.	No. of Comparisons (δ)	Apparent Declination of Comet.			Log. Factor of Parallax in (α)	Log. Factor of Parallax in (δ)	Letter of Reference.
	h	m	s	s		h	m	s	′	″	°					
1896 Nov. 5	7	42	30·3	+0 12·42	Ret.	20	17	9·61	− 9	49·0	Ret.	+23	2 4·6	+9·3254	0·6798	*a*
5	7	42	30·3	−1 35·89	,,	20	17	9·36	+ 7	47·6	,,	+23	2 2·5	+9·3254	0·6798	*b*
8	6	49	50·0	−0 16·81	,,	20	12	33·87	+ 3	28·7	,,	+20	41 26·2	+9·1968	0·6918	*c*
13	7	50	10·2	−0 40·93	25	20	6	9·27	+ 7	5·9	5	+16	57 55·8	+9·4260	0·7558	*d*
26	6	0	36·4	−0 7·94	20	19	55	42·57	+ 6	37·3	4	+ 8	53 27·0	+9·3035	0·8002	*e*
26	6	0	36·4	+1 31·52	20	19	55	42·39	− 7	30·4	4	+ 8	53 24·9	+9·3035	0·8002	*f*
29	6	26	39·2	+0 35·34	Ret.	19	54	10·58	+ 2	33·6	Ret.	+ 7	16 47·2	+9·3939	0·8153	*g*
30	6	22	14·9	−1 13·21	,,	19	53	43·52	+ 6	20·4	,,	+ 6	45 59·7	+9·3939	0·8179	*h*
30	6	22	14·9	−1 8·82	,,	19	53	43·40	−10	1·7	,,	+ 6	46 4·2	+9·3934	0·8179	*i*

Notes

February 22.—Comet tolerably bright, but the selection of definite point for observation difficult. February 23.—The comet seemed much fainter, and the separate measures are very discordant. March 1.—Interruptions from clouds. The stars of comparison too far away in declination; the right ascension very uncertain. March 4.—Observation unsatisfactory; an attempt to repeat the observation with the reticule micrometer failed on account of clouds. March 21.—Comet v. ft.; observation doubtful.

April 21.—Comet tolerably bright, especially towards the south-east, which is the point selected for observation. April 28.—Comet well seen, notwithstanding bright moonlight. May 1.—Comet appears much fainter; the sky rather light, though the Moon had not risen. May 7.—Observation very unsatisfactory with either micrometer; the mean of the whole of the measures is given. May 9.—Interrupted by clouds. May 13.—Comet exceedingly faint; further observation probably impossible. May 16.—Brightness much the same as on May 13; comet just visible; no alteration noticeable. June 2.—Some of the measures rejected evidently had no reference to the comet, which could only be seen at intervals by glimpses.

Nov. 5.—Comet very faint and difficult to pick up; separate measures discordant. Nov. 8.—Only three observations possible on account of cloud. Nov. 26.—Comet very faint, but central stellar condensation suspected.

Assumed Mean Places of Stars of Comparison.

Comet I. 1896 (*Perrine-Lamp*).

Date. 1896.	Star's Designation or Authority for Place.	Mean R.A. 1896·0. h m s	Correction to Mean R.A. s	Mean Declination 1896·0. ° ′ ″	Correction to Mean Dec. ″	Letter of Reference.
Feb. 22	W. B.$_2$ xx. No. 1808	21 0 6·39	−0·76	+27 53 34·8	−10·9	*a*
22	Micrometer obs. from (*a*) and prime vertical	20 58 23·14	−0·77	+27 54 42·6	−10·7	*b*
23	Bonn Obs., vol. vi. No. 4150	21 20 9·55	−0·94	+32 30 33·7	− 8·9	*c*
Mar. 1	A. G. Z. Camb. (U.S.), No. 172	0 20 42·36	−1·44	+50 42 15·8	+ 8·7	*d*
1	„ „ „ No. 166	0 19 42·66	−1·45	+50 59 40·4	+ 8·7	*e*
3	„ „ „ No. 535	1 4 21·76	−1·16	+51 34 32·4	+12·3	*f*
4	„ „ „ No. 703	1 28 18·82	−1·00	+51 37 15·4	+13·8	*g*
4	„ „ „ No. 709	1 29 7·51	−1·00	+51 37 54·7	+13·9	*h*
9	„ Bonn, No. 2312	2 36 29·59	−0·32	+49 56 31·6	+16·8	*i*
9	„ Camb. (U.S.), No. 1246	2 35 34·90	−0·36	+50 1 9·9	+16·4	*j*
11	„ Bonn, No. 2515	2 51 16·73	−0·20	+49 9 15·2	+17·0	*k*
11	„ „ No. 2521	2 51 45·06	−0·20	+49 5 24·0	+17·0	
16	„ „ No. 2999	3 26 57·48	+0·11	+46 55 29·3	+17·1	*m*
19	„ „ No. 3125	3 37 23·38	+0·20	+45 46 14·1	+16·8	*n*
21	„ „ No. 3240	3 46 42·41	+0·25	+45 12 8·4	+16·5	*o*

Comet III. 1896 (*Swift*).

Date. 1896.	Star's Designation or Authority for Place.	Mean R.A. 1896·0. h m s	Correction to Mean R.A. s	Mean Declination 1896·0. ° ′ ″	Correction to Mean Dec. ″	Letter of Reference.
Apr. 21	Leiden Zones, Nos. 11, 243	3 31 2·55	+0·07	+30 46 33·0	+ 9·3	*a*
22	,, ,, No. 148	3 32 19·92	+0·03	+33 30 59·7	+ 9·6	*b*
23	Lund Zones, Nos. 75, 79	3 25 7·02	+0·02	+36 7 42·5	+ 9·6	*c*
24	,, ,, Nos. 92, 105	3 24 20·71	−0·09	+38 47 31·1	+ 9·8	*d*
24	,, ,, Nos. 340, 498	3 27 12·70	−0·09	+38 57 19·8	+ 9·9	*e*
28	A. G. Z. Bonn, No. 2730	3 9 21·32	−0·36	+47 53 44·8	+ 9·6	*f*
28	,, ,, No. 2732	3 9 37·40	−0·36	+47 44 41·0	+ 9·6	*g*
29	Bonn Obs., vol. vi. No. 873	3 5 45·96	−0·45	+50 3 57·0	+ 9·4	*h*
29	A. G. Z. Bonn, No. 2695	3 6 41·19	−0·45	+49 59 24·3	+ 9·4	*i*
May 1	,, Camb. (U.S.), No. 1379	2 59 46·29	−0·64	+53 42 39·1	+ 9·0	*j*
1	,, ,, ,, No. 1381	2 59 52·56	−0·64	+53 42 31·6	+ 9·0	*k*
3	A. G. Z. Helsingfors, No. 2591	2 46 22·80	−0·82	+56 54 26·0	+ 8·0	*l*
3	,, ,, No. 2568	2 44 47·99	−0·82	+56 49 38·7	+ 8·0	*m*
4	,, ,, No. 2404	2 32 25·41	−0·97	+58 12 38·3	+ 6·9	*n*
4	Rümker, No. 1403	2 40 34·84	−0·95	+58 23 44·8	+ 7·2	*o*
5	A. G. Z. Helsingfors, No. 2370	2 29 37·95	−1·05	+59 38 5·8	+ 6·6	*p*
6	,, ,, No. 2337	2 27 40·94	−1·14	+60 39 6·1	+ 6·3	*q*
6	,, ,, No. 2341	2 27 58·03	−1·14	+60 45 32·6	+ 6·3	*r*
7	,, ,, No. 2205	2 16 59·61	−1·27	+62 0 4·4	+ 5·4	*s*
7	,, ,, No. 2249	2 20 24·27	−1·24	+61 44 58·5	+ 5·6	*t*
8	,, ,, No. 2111	2 12 40·96	−1·34	+62 52 21·1	+ 4·8	*u*
8	,, ,, No. 2002	2 8 7·40	−1·35	+62 45 1·6	+ 4·5	*v*
9	,, ,, No. 2058	2 10 45·75	−1·43	+63 56 34·0	+ 4·5	*w*

Date. 1896.	Star's Designation or Authority for Place.	Mean R.A. 1896·0. h m s	Correction to Mean R.A. s	Mean Declination 1896·0 ° ′ ″	Correction to Mean Dec.	Letter of Reference.
May 9	A. G. Z. Helsingfors, No. 2098	2 12 13·35	−1·42	+63 51 24·9	+ 4·6	*x*
10	„ „ No. 1887	2 0 52·96	−1·50	+64 32 32·0	+ 3·5	*y*
10	Greenwich 10-Year Catalogue, 1880, No. 314	1 56 50·70	−1·51	+64 36 13·7	+ 3·2	*z*
11	A. G. Z. Christiania, No. 340	1 46 23·63	−1·63	+65 40 3·5	+ 2·0	*aa*
12	„ „ No. 328	1 41 22·84	−1·66	+66 16 0·5	+ 1·9	*bb*
12	„ „ No. 336	1 44 47·64	−1·66	+66 13 18·0	+ 1·9	*cc*
13	„ „ No. 327	1 40 17·88	−1·74	+66 41 7·7	+ 1·2	*dd*
16	„ „ No. 245	1 12 50·54	−1·80	+68 33 7·5	− 0·4	*ee*
19	„ „ No. 189	0 54 40·55	−1·86	+69 57 38·4	− 3·1	*ff*
19	„ „ No. 177	0 51 21·28	−1·84	+69 56 1·4	− 3·4	*gg*
June 2	Bonn Observations, vol. vi. No. 1099	23 15 53·52	−0·61	+72 44 9·7	− 9·9	*hh*
	Comet I. 1897 (*Perrine, November* 2).					
Nov. 5	A. G. Z. Berlin, No. 7657	20 16 54·91	+2·28	+23 11 34·8	+18·8	*a*
5	„ „ No. 7673	20 18 42·97	+2·28	+22 53 56·1	+18·8	*b*
8	„ „ No. 7610	20 12 48·42	+2·26	+20 37 40·0	+17·5	*c*
13	Munich Observations, vol. i. No. 23406	20 6 47·91	+2·29	+16 50 34·5	+15·4	*d*
26	„ „ „ No. 22619	19 55 48·19	+2·32	+ 8 46 39·0	+10·7	*e*
26	„ „ „ No. 22505	19 54 8·55	+2·32	+ 9 0 44·6	+10·7	*f*
29	„ „ „ No. 22473	19 53 32·88	+2·36	+ 7 14 3·8	+ 9·8	*g*
30	„ „ „ No. 22554	19 54 54·37	+2·36	+ 6 39 29·6	+ 9·7	*h*
30	Bonn Observations, vol. vi. No. 4391	19 54 49·86	+2·36	+ 6 55 56·2	+ 9·7	*i*

Liverpool Observatory: 1897 *May* 12.

Observations of Comets, Perrine, 1896 Nov. 2, and Perrine, 1896 Dec. 8, at the Radcliffe Observatory, Oxford.

(*Communicated by E. J. Stone, Esq., M.A., F.R.S., Radcliffe Observer.*)

The following comet observations were made with the 10-inch Barclay Equatorial, using the ring micrometer, with power 100 :—

Comet Perrine 1896 Nov. 2.

Date.	G.M.T.	Local Sidereal Time.	Observer.	Comet *minus* Star (corrected for Refraction only). R.A.	N.P.D.	No. of Comps.	Apparent R.A. of Comet.	Parallax in R.A. p.	Log. $(p \times \Delta)$.	Apparent N.P.D. of Comet.	Parallax in N.P.D. q.	Log. $(q \times \Delta)$.	Ref.
1896.	h m s	h m s		m s	′ ″		h m s	s		° ′ ″	″		
Nov. 6	7 39 52	22 40 52	W.	+0 18·98	+1 3·9	9	20 15 30·60	+0·15	9·3690	67 45 53·6	3·0	0·6740	(*a*)
9	7 22 38	22 35 25	W.	−1 37·41	+0 13·1	4	20 11 7·45	+0·14	9·3592	70 5 36·0	3·1	0·6975	(*b*)
9	7 22 38	22 35 25	W.	−2 17·03	+6 1·2	4	20 11 7·50	+0·14	9·3592	70 5 36·6	3·1	0·6975	(*c*)
26	7 46 6	0 5 59	R.	...	−0 32·5	7	...	...	...	81 8 56·4	3·6	0·8085	(*d*)
26	7 47 42	0 7 35	R.	−0 4·25	...	7	19 55 39·65	+0·18	9·5173	...	...	...	(*d*)
30	7 1 1	23 36 33	W.	−1 13·17	−5 19·6	4	19 53 43·50	+0·17	9·4825	83 15 1·5	3·5	0·8125	(*e*)
30	7 1 1	23 36 33	W.	−2 36·81	−5 11·9	4	19 53 43·57	+0·17	9·4825	83 14 58·4	3·5	0·8125	(*f*)
Dec. 7	6 24 46	23 27 48	R.	−0 43·96	−2 17·6	6	19 51 17·81	+0·16	9·4719	86 34 36·6	3·5	0·8261	(*g*)

Comet Perrine 1896 Dec. 8.

Dec. 11	8 41 21	2 0 31	W.	−1 55·96	−0 47·6	3	1 10 19·25	+0·24	8·9013	84 38 33 1	18·8	0·8044	(*h*)
12	8 14 2	1 37 4	R.	−0 45·31	+0 52·4	8	1 17 16·32	+0·09	8·4986	85 2 24·5	18·7	0·8066	(*i*)
1897. Jan. 23	8 54 35	5 3 19	R.	−1 35·92	−0 11·7	6	4 44 52·53	+0·05	8·4704	90 20 21·9	12·5	0·8411	(*j*)
26	8 14 55	4 35 23	R.	+0 25·24	−0 31·0	12	4 53 47·69	−0·05	8·4698	90 6 46·6	11·8	0·8398	(*k*)

Observers' Remarks.

(*a*) Observations very difficult owing to the extreme faintness of the object. Instrument white with hoar frost at end of observations, object-glass thinly covered with moisture. Sky hazy.

(*b*), (*c*) Sky very hazy. A small and very faint cluster of three or more stars is near, which in the fog resembles the Comet.

(*d*) Comet fairly bright with a nucleus of about the 12th magnitude. The comparison star is inconveniently close to the Comet for ring-micrometer work. Observed in breaks of rapidly passing clouds. Wind squally.

(*e*) (*f*) Comet is brighter than at my last observation; and, I believe, has a tail, widely fan-shaped, extending northward, but much fainter than coma. Foggy to-night in S.W.

(*g*) Nucleus 12 magnitude. Coma 1½′ diameter.

(*h*) Observations unsatisfactory. Instrument dripping with moisture; wiped object-glass twice, but it was rapidly coated again with condensation. Comet is about 9½ or 10 magnitude; but there is much moonlight.

(*i*) Moonlight strong; centre of a very faint nebulous condensation observed.

(*j*) Comet is a rather faint, nebulous mass, 2′ in diameter, with a condensation.

(*k*) Comet is a faint nebulosity of 2′ diameter, with a condensation. Observations rather difficult.

Assumed Places of the Comparison Stars.

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*a*)	20 15 9·33	+2·29	67 45 7·9	−18·3	Berlin B., A.G. 7639
(*b*)	20 12 42·57	+2·29	70 5 40·1	−17·2	Berlin A., A.G. 8079
(*c*)	20 13 22·24	+2·29	69 59 52·7	−17·3	Berlin A., A.G. 8087
(*d*)	19 55 41·57	+2·33	81 9 39·7	−10·8	Barclay Equatorial comparisons with Schjellerup, 7741, Lamont, 22619; Lamont, 22819; Glasgow (1870), 5000

Ref.	Mean R.A.	Reduction to Apparent R.A.	Mean N.P.D.	Reduction to Apparent N.P.D.	Authority.
	h m s	s	° ′ ″	″	
(*e*)	19 54 54·31	+2·36	83 20 30·8	−9·7	Bonn vol. vi. +6° 4393
(*f*)	19 56 18·02	+2·36	83 20 28·1	−9·8	Bonn vol. vi. +6° 4401
(*g*)	19 51 59·37	+2·40	86 37 2·1	−7·9	Barclay Equatorial comparisons with Albany, 6936
(*h*)	1 12 11·01	+4·20	84 39 47·9	−27·2	Albany A.G., 353
(*i*)	1 17 57·41	+4·22	85 1 59·0	−26·9	Radcliffe Transit-circle observation, 1896 Dec. 15
(*j*)	4 46 26·61	+1·84	90 20 37·0	−3·4	Radcliffe Transit-circle observations, 1897 Feb. 17, 20
(*k*)	4 53 20·60	+1·85	90 7 20·7	−3·1	Radcliffe Transit-circle observations, 1897 Feb. 17, 20

In the computation of the parallaxes the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distances, Δ, are taken from the *Astronomische Nachrichten*, as follows:—(*a*), (*b*), (*c*), No. 3386; (*d*), (*e*), (*f*), (*g*), No. 3387; (*h*), (*i*), No. 3391; (*j*), (*k*), No. 3396.

Observation of Comet Perrine (1896 Dec. 8) with the Transit-Circle.

Date. 1896.	G.M.T. of Transit. h m s	Observer.	Apparent R.A. of Comet. h m s	Apparent N.P.D. of Comet. ° ′ ″	Parallax N.P.D. *q*. ″	Log. (*q* × Δ).	Observer's Remarks
Dec. 11	7 51 2	W.	1 10 3·88	84 37 49·3	18·8	0·8035	Sky very thick; moonlight and haze. Observation very difficult. The microscope readings have been increased by 1 rev. = 1′

In the computation of the parallax the adopted value of the Sun's mean horizontal parallax is 8″·85; and the geocentric distance, Δ, is taken from the *Astronomische Nachrichten*, No. 3,391.

Observers: W., Mr. W. Wickham; R., Mr. W. H. Robinson.

Zodiacal Radiants of Fireballs. By W. F. Denning.

I have previously pointed out that the majority of large fireballs observed *move slowly, are directed from radiants in the western half of the sky and in the neighbourhood of the horizon* (*Monthly Notices*, vol. liv. pp. 342 and 539). They appear, in fact, to form a special class of bodies, and to offer well-marked distinctions to the ordinary shower-meteors generally moving swiftly from radiants high in the eastern sky.

To what has been already said on this subject I may now add that the majority as well as the most prominent of the fireball radiants apparently cluster in a girdle conforming approximately with the position of the ecliptic. This is not an inviolable law of distribution, for many exceptions to it can be found, but it agrees with the weight of the evidence, and much of this is of a very suggestive and significant kind.

There are probably few persons who have occupied themselves in the comparison and assortment of well-marked fireball radiants, but those who have will remember the brilliant Cancrids of January, Sextantids of February, β Leonids of March, Virginids and Librids of April, Scorpiids and Sagittarids of June, Aquilids, Capricornids and Aquarids of July and August, Piscids of September, Arietids of October, Taurids of November, and Geminids of December.

I have compiled the following table as representing approximately the facts observed :—

	R.A. Fireball Radiants.		Chief Positions.
	°		° °
Jan.	110	Geminids, Cancrids	97 + 29 110 + 24 132 + 21
Feb.	140	Sextantids, Hydrids	145 + 5 148 − 12
Mar.	170	Sextantids, β Leonids	175 + 10
April	200	Virginids, Librids	208 − 10 216 − 8
May	230	Serpentids, Scorpiids, Ophiuchids	228 − 3 235 − 15 244 + 7
June	260	Scorpiids, Sagittarids	250 − 20 269 − 23

	R.A. Fireball Radiants.		Chief Positions.
	°		°
July	290	Antinoids, Aquilids	282 − 13 285 − 21 296 − 0 303 + 12
Aug.	320	Capricornids, Aquarids	303 − 12 317 ± 11 326 − 9 339 − 12
Sept.	350	Piscids	348 ± 0 355 + 5 2 − 3 6 + 12
Oct.	20	Piscids, Arietids	14 + 7 33 + 18 40 + 20
Nov.	50	Arietids, Taurids	48 + 22 55 + 17 62 + 22
Dec.	80	Aurigids, ζ Taurids, Geminids	77 + 32 80 + 23 108 + 25

It is not to be assumed from the table that the approximate R.A. of the principal fireball-radiants exhibits a regular arithmetical increase of 30° per month, but that this rate of progression seems best to generally satisfy the observations. The R.A. given is chiefly based on the very well-defined April fireball-radiants in Virgo and Libra, the Scorpiid radiant in June, the Capricornid radiant in August, the Arietid radiant in October, and the Taurid radiant in November. Any system of R.A.'s for the different months, to be conformable with the principal showers of large meteors, must accommodate these specially productive and well-known systems.

In striking corroboration of the preference for the zodiac shown by fireball-radiants it may be mentioned that the well-defined positions in *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, and *Aquarius* are visible, notwithstanding the circumstance that they are below the equator, and therefore unfavourably presented in northern latitudes. Yet they form a well-marked girdle along the zodiac, while a similar distance north of the equator few such radiants are manifested. Again, if we turn to the region embraced by *Pisces*, *Aries*, *Taurus*, *Gemini*, *Cancer*, and *Leo* there

appears the same extensive girdle, while south of the equator not many fireball radiants are known. But, as before stated, the zodiacal radiants of fireballs are not nearly inclusive of all such systems, for there are instances in *Cygnus* (293°+52° August, and 304°+54° September), *Cepheus* (330°+57° January–March, and 335°+71° August–September), *Cassiopeia* (20°+57° April), *Draco* (262°+63° October), *Pegasus* (336°+35° September), *Ursa Major* (213°+53° August), *Perseus* (47°+44° April), &c., &c., but the fireballs from the region of the zodiac seem to have been the most numerous, and the radiants derived from them more satisfactory than the others.

These large meteors would therefore appear to be revolving not only in direct orbits, but to exhibit small inclinations like the Jovian family of comets.

It is most important that large meteors, whenever and wherever they appear, should be accurately recorded in order to acquire the material which is absolutely necessary in an investigation of this kind. In the present state of our knowledge it is difficult to draw certain conclusions, the available data being not only deficient, but often vitiated by unreasonably large errors. In view of the suggestive and interesting questions involved, it is hoped observers of the brilliant and isolated forms of meteoric phenomena offered by fireballs will be particular in registering their apparent paths amongst the stars, and durations of flight, so that trustworthy results may accumulate more rapidly than in previous years

Bristol: 1897 *April* 11.

The New Thompson Photographic Telescope at the Royal Observatory, Greenwich.

The Astronomer Royal announced that the new instrument, presented by Sir Henry Thompson, had been mounted on the Physical Observatory under the Lassell Dome, and was practically completed and in working order, though further adjustment of the object-glass would be required.

He exhibited some photographs of the Moon, (i) taken at the principal focus and giving an image about 2½ inches in diameter, (ii) enlargements made at the telescope by the use of a secondary magnifier, giving an image 11½ inches in diameter.

MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. LVII. JUNE 11, 1897. No. 8

A. A. COMMON, LL.D., F.R.S., Vice President, in the Chair.

Professor Henry C. Lord, Director of the Emerson McMillin Observatory, Ohio State University, Columbus, Ohio, U.S.A.,

was balloted for and duly elected a Fellow of the Society.

The following Candidate was proposed for election as a Fellow of the Society:—

William James Stewart Lockyer, M.A., Ph.D., 16 Penywern Road, South Kensington, S.W. (proposed by J. W. L. Glaisher).

Eighty-one presents were announced as having been received since the last meeting, including, amongst others:—

Cayley's Collected Mathematical Papers, vol. xii., presented by the Cambridge University Press; Cambridge Observatory, Astronomische Gesellschaft Catalogue, Zone $+25°$ to $+30°$, presented by Sir R. S. Ball; S. Glasenapp, Mesures Micrométriques d'Etoiles Doubles, presented by the St. Petersburg Astronomical Observatory; Harvard Observatory Annals, vol. xxviii., part 1, and vol. xxxvi., presented by the Observatory; L. O. Hesse's Gesammelte Werke, presented by the Munich Academy; G. Müller, Photometrie der Gestirne, presented by the author; E. C. Pickering, Navigation in fog, presented by the author; E. J. Stone and H. H. Turner, Tables for facilitating computa-

tion of star constants, presented by Professor Turner; C. A. Young, The Sun, new edition, presented by the author; Photographs of Spectra taken with the Bruce spectroscope, presented by Mr. Newall; Various volumes of MS., presented by Messrs. W. Wesley and Son.

Note on the Mean Motions of the Lunar Perigee and Node.

By Professor Ernest W. Brown, Sc.D.

The values given in my paper in the *Monthly Notices* 1897 March, for the mean motions of the perigee and node require slight corrections to make the comparison with Hansen's values complete. Although these corrections are much less than the possible errors which I thought it necessary to assign, and may be supposed to be included therein, there is a perceptible effect on the differences between the various results in the case of the perigee, and further my theoretical result for it comes much closer to that of Hansen. The nature of the correction is as follows:—

The disturbing function is of the form $m'Q$, where m' is the mass of the Sun and Q is a function of the solar and lunar coordinates. As is usual, we put $m'=n'^2a'^3$, instead of $m'=n'^2a'^3-E-M$, where n', a' are the solar mean motion and mean distance, and E, M, the masses of the Earth and Moon. Hansen uses the latter, which is the correct substitution for m'.

The correction is in general sufficiently accounted for if we multiply all the terms of the first order of the disturbing forces by

$$1-\frac{E+M}{m'}=1-\frac{1}{330000}, \text{ approximately;}$$

those of the second order by

$$\left(1-\frac{E+M}{m'}\right)^2=1-2\frac{E+M}{m'}, \text{ approximately.}$$

It is in all cases sufficient to consider the terms of the first order only in making this correction, except in the motion of the perigee, where the terms depending on the square of the disturbing forces are about equal in magnitude to those depending on the first power.

Hence, putting ϖ_1, θ_1 for the mean motions of the perigee and node, the corrections will be, with a sufficient approximation,

$$-\frac{1}{2}\varpi_1\cdot\frac{E+M}{m'}-\frac{1}{2}\varpi_1\cdot 2\frac{E+M}{m'}=-\frac{3}{2}\cdot\frac{1}{330000}\varpi_1,$$

and

$$-\theta_1\cdot\frac{E+M}{m'}=-\frac{1}{330000}\varpi_1,$$

respectively.

The theoretical values of the annual mean motions, given in the paper, and there numbered (i), are

$$+146\ 435''{\cdot}3 \pm 1''{\cdot}8, \qquad -69\ 679''{\cdot}5 \pm 1''{\cdot}1.$$

The corrections examined above are therefore

$$-0''{\cdot}7, \qquad +0''{\cdot}2;$$

making my theoretical values

$$+146\ 434''{\cdot}6 \pm 1''{\cdot}8, \qquad -69\ 679''{\cdot}3 \pm 1''{\cdot}1.$$

The former is now quite close to the corrected value of Hansen—that previously numbered (iv)—which is $146\ 434''{\cdot}9$. The difference from the observational value is now $1''{\cdot}0$, but, as I remarked before, no argument can be based on this. The argument in the case of the node is quite unaffected; the error of $2''{\cdot}0$ in Hansen's theoretical result remains.

Haverford College, Pa.:
1897 *May* 1.

On some Spectroscopic Determinations of Velocity in the Line of Sight made at the Cambridge Observatory. By H. F. Newall.

The present note gives some results recently obtained in determinations of velocity in the line of sight with the Bruce spectroscope attached to the 25-inch refractor (the Newall telescope) of the Cambridge Observatory (*Monthly Notices*, lvi. p. 98).

The instrument was used for determinations of velocity and for the careful study of a few spectra throughout the year 1896; but on account of more or less systematic differences between the results obtained from the photographs and the results obtained by Dr. Vogel at Potsdam, it was necessary to subject the instrument to an even more searching investigation than it received in the course of the first adjustment. The difficulty has been the setting of the comparison spectrum, and the investigation has been of a very troublesome kind, as has already been indicated in the annual reports (see present vol. *Monthly Notices*, p. 250). The instrument is now apparently in excellent adjustment. The test photographs are completely satisfactory, and moreover the velocities deduced for several bright stars are in good agreement with those deduced by Dr. Vogel from photographs taken with the Potsdam spectrograph.

The cause of the systematic discrepancies above referred to has been discovered. A minute deflection of the collimator had been produced every time the comparison prisms were used. The deflection was traced to a deformation of a plate at the end of the strong frame of the spectroscope, brought about by altera-

tions in the pressure of a spring attached to it. It may be stated that the observed discrepancies in the determination of velocity—amounting to about 20 kilometres per second—would be accounted for by a movement of the slit of the spectroscope through about 7 thousandths of a millimetre. The deflection produced a shift of the lines in the comparison spectra relatively to the corresponding lines in the star spectrum. The unexpected position of the strain made it very difficult to trace, and the search was made all the more difficult by the fact that the effect was variable in magnitude.

The velocities quoted in the following table as examples of results recently obtained must not be regarded as more than provisional except in the case of *α Boötis*. More photographs are needed

α Tauri.

Plate C. 411. 1897 March 4, $9^h\ 48^m$. Exposure 30 minutes.

Temperature 4°·7 to 4°·1 C.

Wave-length of line.	Velocity deduced relative to Earth.
λ4308	+87·2
4326	+88·4
4384	+78·3
4405	+64·2
4415	+75·7
Mean ...	+78·8
Correction for Earth's orbital velocity ...	−29·6
Velocity relative to Sun	+49·2 kilometres per second.

[Vogel +47·6; Scheiner +49·4.]

α Orionis.

Plate C. 408. 1897 March 3. Exposure 55 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4315	+29·3
4370	+49·5
4405	+37·3
4415	+37·4
Mean ...	+38·4
Correction for Earth's orbital velocity ...	−27·8
Velocity relative to Sun	+10·6 kilometres per second.

[Vogel +15·6; Scheiner +18·8.]

α Canis Minoris

(2 plates, 5 lines on each).

(1) Plate C. 405. 1897 Feb. 17, $12^h\ 10^m$. Exposure 36 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	− 3·6
4308	+13·3
4384	+23·3
4405	+14·8
4415	+16·3
Mean ...	+12·8
Correction for Earth's orbital velocity ...	−16·3

Velocity relative to Sun − 3·5 kilometres per second.

(2) Plate C. 409. 1897 March 3, $10^h\ 54^m$. Exposure 33 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	+ 7·9
4308	+17·0
4384	+14·8
4405	+17·9
4415	+25·2
Mean ...	+16·6
Correction for Earth's orbital motion ...	−21·5

Velocity relative to Sun − 4·9 kilometres per second.

[Vogel −7·9; Scheiner −10·5.]

β Geminorum.

(1 plate, 5 lines).

Plate C. 414. 1897 March 19, $9^h\ 53^m$. Exposure 45 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	+22·8
4308	+28·0
4384	+23·5
4405	+28·9
4415	+29·3
Mean ...	+26·5
Correction for Earth's orbital motion ...	−27·2

Velocity relative to Sun − 0·7 kilometre per second.

[Vogel +1·9; Scheiner +0·4.]

γ Leonis, bright component

(2 plates, 3 lines each).

(1) Plate C. 419. 1897 March 24, $10^h\ 47^m$. Exposure 90 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−21·7
4405	−25·4
4415	−28·8
Mean ...	−25·3
Correction for Earth's orbital motion ...	−17·0
Velocity relative to Sun	−42·3 kilometres per second.

(2) Plate C. 423. 1897 April 10, $11^h\ 13^m$. Exposure 61 minutes.

Wave-length of line.	Velocity deduced relative to Earth.
λ4370	−13·0
4405	−20·2
4415	−10·0
Mean ...	−14·4
Correction for Earth's orbital velocity ...	−23·1
Velocity relative to Sun	−37·5 kilometres per second.

[Vogel −36·5; Scheiner −40·5.]

Test Photographs.

Diffused Sunlight from Cloud.

(1) Plate C. 407*d*. 1897 March 2.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−7·6
4272	+1·7
4308	+1·3
4384	−6·7
4405	+0·2
4415	−0·7
Mean ...	−1·9 kilometre per second.

(2) Plate C. 419*a*. 1897 March 27.

Wave-length of line.	Velocity deduced relative to Earth.
λ4261	−1·2
4308	+5·8
4326	−0·6
4384	−0·6
4405	+1·8
Mean	... +1·0 kilometre per second.

The velocity of *α Boötis* has been determined also by Belopolsky and Keeler, and accordingly this star was selected for special study, and the results are given in the table on page 573.

In taking the photographs, the following procedure is adopted. The slit is set parallel to the direction of daily motion and is partly covered by suitable diaphragms, which are movable, so that parts of the slit may be covered or exposed at the will of the observer. An electric spark between iron points is used as the terrestrial source of light for the comparison spectrum. First two exposures are made for the spectrum of iron; next the star spectrum is taken; and after the exposure for the star, two more exposures are made for the iron. Thus five spectra are set side by side on the one plate.

Iron taken before the star
Iron taken after the star
Star spectrum
Iron taken before the star
Iron taken after the star

The outer iron spectra are used for adjusting the wire of the micrometer to parallelism with the lines in the spectrum, the wire being set to bisect a line in the pair of spectra taken either before or after the star spectrum. The measurements are made only on the two inner iron spectra and on the star spectrum. The width of the five spectra is so small, that the curvature of the lines is not appreciable—an advantage largely due to the fact that only one prism is used. The width of the star spectrum is about 0·4 millimetre, and this is attained when the star-trail backwards and forwards along the slit amounts to about 0·2 millimetre.

The light from the spark passes into the slit after being reflected three times by reflecting prisms, and after passing through a lens. That satisfactory results are obtained from the

use of a spark situated off the *real* axis of the collimator is attributed in part to the convenience of the reflecting slit (Dr. Huggins's arrangement), by which the observer is enabled to see the image of the whole spark whilst it is being adjusted on the slit, and in part to careful adjustment of the reflecting prisms and to exceedingly careful focussing of the collimator.

The following method of focussing the collimator has been found by far the most satisfactory. The collimator is focussed first by visual observations, carried out according to Schuster's method, the whole aperture being used. Then a diaphragm is put on, consisting of an opaque card with a circular aperture half that of the collimator lens. The collimator of the Bruce spectroscope has an aperture of two inches. Hence the diaphragm lets a one-inch beam pass. A photographic plate is put into the camera of the spectroscope, and two exposures are made on the same plate, one being got when the one-inch beam passes through the thick part of the prism, the other when the one-inch beam passes through the thin part. If the collimator is properly focussed, there is no shift or displacement of the lines in the two spectra. The existence of shift is a sign that the collimator is not adjusted (assuming that the prism and lenses are not faulty). The rationale of the method is clear, and when the collimator has been focussed in this manner the definition of the photographs is very good over a very considerable range of spectrum ; the aberrations due to unsymmetrical passage through the prism when the incident beam is not properly collimated being very noticeable. Moreover, when the collimator has been focussed in the way described, a slight maladjustment of the axis either of the pencil of starlight or of the pencil of iron-spark-light relative to the axis of the collimator appears to be of no importance.

The results obtained in the case of *α Boötis* are set forth in the following table. Entirely independent measurements have been made by myself (N.) and by my assistant, A. W. Goatcher (G.), from seven plates of *α Boötis* taken since the last alterations were made to the spectroscope.

The scale of the photographed spectra is such that one millimetre in the length of the spectrum corresponds to 20·8 tenth-metres in the neighbourhood of λ 4260 and to 24·2 tenth-metres in the neighbourhood of λ 4415. The microscope used in measuring the photographs has a magnifying power of 21, and the micrometer screw is an excellent screw by Cooke. The average value of a revolution of the micrometer head expressed in terms of kilometres per second is 385 km/sec.

The velocity of light has been taken as 3×10^5 km/sec, and the solar parallax adopted is 8″·838.

α Boötis.

(7 plates).

Measurements made by N.

Plate. Date 1897.	C. 422. Apr. 8^d13^h.	C. 424. Apr. 10^d13^h.	C. 427. Apr. 14^d13^h.	C. 428. Apr. $14^d13\frac{1}{2}^h$.	C. 429. Apr. 27^d12^h.	C. 430. May 1^d12^h.	C. 433. May 3^d13^h.
λ4250·3	...	− 9·7	...	...	...	...	...
4250·9	...	− 3·9	...	...	...	...	...
4260·6	−21·2	−11·0	− 8·3	−16·1	+ 1·0	0·0	− 1·6
4308	− 8·0	− 2·1	+ 2·1	− 9·5	−4·0	−1·1	+ 7·8
4315	...	...	−11·9	...	...	...	...
4370	− 5·9	− 1·9	− 1·0	−12·3	...	−3·2	...
4384	−12·9	− 8·0	− 9·2	− 7·7	−6·6	...	...
4405	− 3·3	− 6·7	− 3·9	+ 0·8	−3·5	+8·2	+13·1
4415	− 6·7	− 3·3	+ 0·5	− 5·8	−3·0	+6·7	+13·8
4427	−15·4	− 2·8	+ 0·3	− 2·2	...	...	+10·4
Mean ...	−10·5	− 5·5	− 3·9	− 7·5	−3·2	+2·1	+ 8·7
Corr. to ⊙	+ 1·9	+ 1·0	− 0·7	− 0·7	−6·2	−7·9	− 8·7
Vel. rel. to ⊙	− 8·6	− 4·5	− 4·6	− 8·2	−9·4	−5·7	0·0
Prob. error	± 1·5	± 0·8	± 1·2	± 1·5	±0·8	±1·5	± 2·4

Mean for 7 plates − 5·9 ± 0·8 (N)

Measurements made by G.

λ4250·3	−13·8	−14·7	...	...	...	...	...
4250·9	...	− 3·1	...	...	...	...	...
4260·6	−17·4	−14·2	−13·3	−16·6	−3·7	0·0	− 3·5
4308	− 7·5	− 2·3	− 0·3	− 6·4	...	+2·8	+ 8·4
4315	...	...	−12·0	...	−4·0	...	...
4370	− 5·2	− 4·6	− 2·2	−14·2	...	...	...
4384	−20·6	− 9·0	− 6·9	− 7·7	−4·7	...	...
4405	−12·0	− 4·1	− 6·2	− 3·0	+0·2	+2·7	+ 7·1
4415	− 8·1	− 1·0	− 0·2	− 2·0	+0·5	+2·5	+11·5
4427	− 8·9	−16·1	− 4·0	− 0·3	...	...	...
Mean ...	−11·7	− 7·7	− 5·6	− 7·2	−2·3	+2·0	+ 5·9
Corr. to ⊙	+ 1·9	+ 1·0	− 0·7	− 0·7	−6·2	−7·9	− 8·7
Vel. rel. to ⊙	− 9·8	− 6·6	− 6·3	− 7·8	−8·6	−5·9	− 2·8
Prob. error	± 1·3	± 1·3	± 1·2	± 1·6	±0·7	±0·5	± 2·2

Mean for 7 plates −6·8 ±0·6 (G)

[Vogel −7·0; Scheiner −8·3; Belopolsky −5·7; Keeler −6·8.]

The lines measured have been selected in the star spectrum from a great number of iron lines, on account of ease in identification. A comparison of the solar spectrum, as photographed with small dispersion, and as represented in Rowland's map, which has a dispersion about sixty-six times as great, shows that the iron lines are involved in groups, so that the choice of lines is practically decided by the predominance of an iron line amongst its immediate neighbours. The *group* is bisected in the photograph, but the bisection does not necessarily coincide with the true position of the iron line in the group. Consequently each line chosen will give a velocity which is affected with an error in identification. If enough lines are measured, these errors might be supposed to cut one another out. The discussion of the measurements of *α Boötis* will show what is to be expected. (See the table below.)

The determination of velocity from a single line is based on eleven micrometer settings—three on the iron line in the spectrum taken at the beginning of the exposure, and three on the iron line taken at the end, and five settings on the group which represents the iron line in the star spectrum. The difference between the means for the iron lines is the shift due to change of temperature or to change in the position of the instrument during the exposure. It is assumed that this change is a linear function of the time, and the displacement of the star line or group relative to the mean of the initial and final positions of the iron line is taken to get the velocity. The mean of about seven velocities deduced from as many lines in a plate is regarded as the velocity deduced from the plate.

It appears from the measurements that the probable error of the velocity determined from a single line (eleven micrometer settings), on the assumption of no error of identification, is between $\pm$ 0·2 and $\pm$ 0·6 km/sec according to the goodness of the photograph.

The probable error of the velocity deduced from about seven lines on a plate is between $\pm$ 0·5 and $\pm$ 1·5 km/sec, again assuming no errors in identification.

The probable error of the velocity deduced from seven plates is about $\pm$ 0·7, on the assumption that *α Boötis* has a constant velocity relative to the Sun, and is not a spectroscopic double-star.

With a view of seeing how far the velocity deduced from a given line on the seven plates would give evidence of a calculable error of identification, the mean velocity relative to the Sun for each of seven lines was got out.

The group of lines, which was bisected in the micrometer setting, was compared in each case with Rowland's map ; and the attempt was made to form an estimate of the displacement of the centre of the group from the true centre of the iron line which predominated in the group, weight being given to the foreign lines involved in the group according to the intensity of

the lines as recorded in Rowland's tables. This displacement was expected to be in a sense the error in identification of the true iron line in the star spectrum. The velocity corresponding to the displacement was then computed, and the results are entered in the last column of the table. The assumption underlying this, viz., that the spectrum of *α Boötis* is similar in detail to that of the Sun, appears to be supported by a comparison of the spectra.

	Velocity relative to Sun. N.	G.	Residuals. N.	G.	Computed Error of Identification.
λ4260·6	−11·0	−12·7	+5·4	+6·0	+7·7
4308	− 5·2	− 3·3	−0·5	−3·4	+5·6
4370	− 5·6	− 6·0	−0·1	−0·7	0·0
4384	− 9·0	−10·6	+3·3	+3·9	0·0
4405	− 2·7	− 5·1	−3·0	−1·6	+1·4
4415	− 2·8	− 2·5	−2·9	−4·2	−4·1
4427	− 3·7	− 6·8	−2·0	+0·1	+4·1
Mean ...	− 5·7	− 6·7 km/sec	Mean		... +2·5 km/sec

The material is in reality too slight for a completely satisfactory comparison; and yet as far as it goes, it affords means of estimating the errors involved in the use of small dispersion. One point is made clear by the investigation, viz. that little or no advantage, so far as the elimination of the error of identification is concerned, would be gained by *doubling* the dispersion and resolving power of the spectroscope; for the disturbing lines in the groups selected would not be separated from the iron lines without a considerably greater increase.

α Geminorum (*Castor*).

Two excellent photographs of the spectra of the components of α Geminorum were obtained in 1896 November, each having a spectrum of the faint star in the system between two spectra of the bright star. It was observed that (i.) the spectrum of the bright star was similar to that of *α Lyræ*; (ii.) the spectrum of the faint star resembled that of *α Cygni* very closely; (iii.) lines common to the two spectra showed considerable relative shift; (iv.) the shift of the lines in the faint star spectrum was towards the red in one photograph and towards the blue in the other.

The photographs have been measured with the following results:—

(1) Plate C. 382. 1896 Nov. 4, $13^h\ 35^m$ to $15^h\ 9^m$. Observer, N.

Exposures	Bright component	30 minutes.
	Faint „	50 „
	Bright „	12 „

	Velocity of Faint relative to Bright.
λ4290	−50·3
4326	−35·2
4395	−41·1
4482	−41·8
4550	−43·0
Mean ...	−42·3 km/sec. (N)

(2) Plate C. 385. 1896 Nov. 5, $11^h\ 47^m$ to $13^h\ 14^m$. Observer, G.

Exposures { Bright component ... ... 25 minutes. Faint „ ... ... 50 „ Bright „ ... ... 10 „

	Velocity of Faint relative to Bright.
λ4290	+28·9
4308	+29·6
4352	+37·1
4418	+32·3
4482	+23·0
4550	+33·8
Mean ...	+30·8 km/sec. (N)

These photographs were taken without any comparison spectra last autumn, before the cause of difficulty with the comparison spectra was found out; but it is clear that they are not open to the objection that has necessitated the rejection of results relating to the determination of velocity with the Bruce spectroscope before 1897 February. But as the cause of vitiation was not known, the large shifts observed in the spectra of *Castor* now dealt with were regarded with a suspicion that is now removed. The velocities deduced are, therefore, regarded as completely trustworthy.

Belopolsky has found (*Astrophysical Journal*, vol. v. p. 1, 1897) that the faint component of *Castor* is a spectroscopic binary, and that within a period of 2·91 days the velocity of the star relative to the Sun passes through a series of changes, ranging between +35 and −45 km/sec. Belopolsky has deduced as the time of periastron passage the date 1896 February $28{\cdot}82 \pm 2{\cdot}91\ n$. Assuming this period, the interval since the preceding periastron passage for each of the photographs above referred to is given below; the corresponding velocities deduced from Belopolsky's orbit are also given. Assuming that the velocity (relative to the Sun) of the system a_1 (faint star and invisible companion) is the same as that of a_2 (bright

star), then the observed velocities above recorded should be comparable with those computed from Belopolsky's data.

			$\frac{ds}{dt}$ km/sec.	Cambridge Obs.
C. 382	1896 Nov. 4·60	= 1896 Feb. 28·82 + (2·91 d × 85) + 2·44 d	+39	−42·3
C. 385	1896 Nov. 5·53	= 1896 Feb. 28·82 + (2·91 d × 86) + 0·46	−39	+30·8

The photographs show a change of velocity quite comparable with that discovered by Belopolsky, but exactly opposite in phase. The period $2^d{\cdot}91$ is not accurately enough known for the calculation of an ephemeris so far ahead as seven months. It would appear that an odd number of half periods has been lost or gained between April and November. Belopolsky's discussion of thirty-two photographs pointed to some possible variation in the period, and it is to be hoped that he has secured more evidence in the present year.

The photographs obtained at Cambridge, however, appear to support Belopolsky's most interesting discovery, that in the system of *Castor* two periods must now be recognised, one about 1000 years, the other probably less than three days.

On a New Binary Star with a Period of 5½ *Years* (β 883).

By T. J. J. See, A.M., Ph.D. (Berlin).

For several months I have been practically certain that the double star β 883=Lalande 9091, $\alpha = 4^h\ 44^m\ 33^s{\cdot}0$, $\delta = +10°\ 52'$ (1875·0) is revolving in a period of about 5·5 years, and thus describing its orbit in less than one-half the time required for the most rapid system heretofore known; but it seemed desirable to withhold any announcement of such an extraordinary result until the observations should remove every reasonable doubt of the correctness of the conclusion. Indeed, this hypothesis first presented itself to my mind in the summer of 1895, when I was examining the orbits of all known binaries with a view to selecting those most accurately determined for incorporation into the work recently published (*Researches on the Evolution of the Stellar Systems*, vol. i.).

Professor Schiaparelli had very kindly communicated by private letter a number of his unpublished obvervations of this star, and on combining these with other measures in my possession it seemed clear that only a period of about 5·5 years would satisfy the observations. Professor Burnham, however, did not regard the evidence as conclusive, and I decided to wait till further measures were available. On entering upon the measurement of southern double stars I felt that notwithstanding the northern position of this object the great interest attach-

ing to it would justify occasional examination with the Lowell 24-inch refractor. Accordingly I observed it at Flagstaff in September, and have since continued the observations every month, except when the Observatory was in process of removal to Mexico. These observations since 1896 September furnish the key to the situation; and as the Sun is now rapidly overtaking the star, and it cannot be followed much longer this year, the present is a favourable time to present to the Society the results at which we have arrived. In the sweeps for new double stars I am assisted by Mr. W. A. Cogshall, S.B., who generally examines all objects of difficulty, and at different times has secured a considerable number of measures. His work has been done with care and precision, and I have valued his judgment in all cases of doubt. In our observations of this star we are in entire accord.

Individual Observations of β 883.

t	θ_o	ρ_o	Observers.	Remarks.
	°	"		
1879·00	[197·5] 17·5	0·35	Burnham	
1887·096	84·3	0·15	Schiaparelli	Very difficult.
·170	85·0	0·15	,,	,, ,,
·172	84·7	0·15	,,	,, ,,
1888·055	119·5	0·18	,,	
·066	129·4	0·18	,,	
·142	...	...	,,	Simple.
1889·017	137·0	...	,,	Doubtful.
·065	...	...	,,	Simple.
·176	158·8	0·15	,,	
·192	158·3	0·20	,,	
·195	144·2	0·25	,,	+180°·0?
1890·130	200·7	0·15	,,	Doubtful.
·132	206·9	0·15	,,	,,
·149	202·8	0·18	,,	,,
1891·14	Single	Many nights	Burnham	
·146	...	...	Schiaparelli	Single.
·149	...	...	,,	,,
·785	125·2	0·12	Burnham	
1892·057	116·4	0·06	,,	
·060	127·8	0·12	,,	
1893·072	...	...	Schiaparelli	Single.
1894·146	...	...	,,	,,
·165	...	...	,,	,,
·65	173·5	0·20	Barnard	

t	θ_o	ρ_o	Observers.	Remarks.
	°	″		
1895·146	...	...	Schiaparelli	Uncertain.
·745	186·0	0·43	See	Good images.
·746	186·8	0·35 ±	,,	Separated.
·745	188·9	...	Moulton	,,
1896·692	9·9	0·17 ±	See	Distinctly elongated, but no trace of separation.
·693	12·0	0·14 ±	,,	
·728	28·7	0·25 ±	,,	Elongated, but not separated.
·843	22·8	0·18 ±	,,	Elongation very distinct.
·844	23·8	0·17 ±	,,	Notched under power of 1000.
1897·028	34·6	0·28 ±	,,	Well separated, but very close.
·118	34·2	0·28	,,	Distinctly separated. Good measures.
·162	35·5	0·25	,,	Nicely separated.
·162	36·0	0·35	Cogshall	
·192	37·8	0·35	See	Distinctly separated, with black line between.
·193	37·1	0·35 ±	,,	Distinctly separated, with black line between.
·192	35·5	...	,,	Angle certainly not smaller than this value.

In September last the star was moderately elongated in angle 11°, but no trace of separation could be seen, though examined under good seeing with a power of 1000; now it is distinctly separated with a black line between the components, with a power of only 500, and cannot be regarded as a very difficult object for the great Telescope.

The distance at present can hardly fall short of 0″·32, while in September it certainly was not more than half this value.

This object was discovered by Burnham with the Chicago 18½-inch Clark refractor in 1879·0, and measured on one night. The components of the close pair (there is a third component in 152°·2, 18″·22, 13th magnitude) have always been noted as nearly equal (generally as 7·8 and 8), differing at most by one or two tenths of a magnitude; and hence I suspect that the first angle given as 17°·5 ought to be increased by 180°. If the stars are sensibly equal the observers almost involuntarily adopt the smaller of the two possible position-angles. Our recent observations give an additional ground for this correction by showing that the stars are not separated in angle 17°·5, and hence it is improbable that the distance would have been given as 0″·35.

The observations of Schiaparelli in 1887, 1888, 1889, 1890, show that the motion is rapid, and indicate that the period is only a few years. In 1891 the star was single to Schiaparelli and also to Burnham, who examined it on several nights; which would imply that the companion was then in periastron.

In 1891·97 it was observed by Burnham, who concluded that 100° had been swept over by the radius vector since 1879·0. In 1894·65 Professor Barnard observed it, at my request, and found the angle to be 173°·5. While observing double stars at Madison in September 1895, I took occasion to measure this object, and found that it was close, but nicely separated with the 15½-inch refractor.

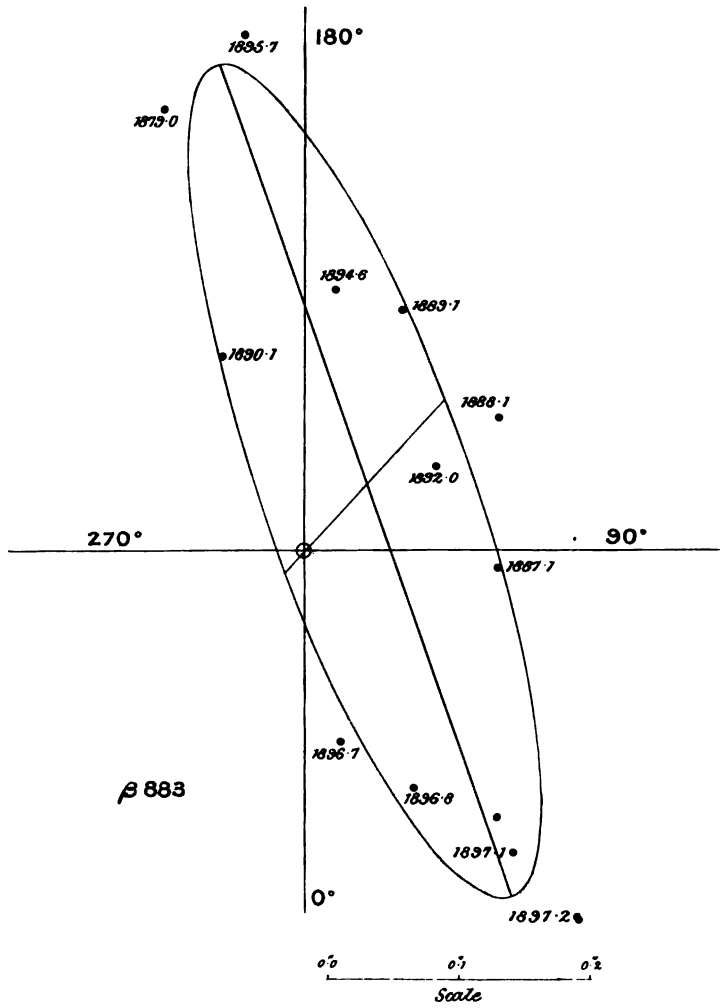
Mr. Moulton's measure was in substantial agreement with my own, and neither of us regarded it as a very difficult object for a good telescope. I have no record of any subsequent measures until the beginning of our work at Flagstaff. In September it certainly was slightly elongated, but not a trace of separation could be seen. In our subsequent observations we were equally unable to get evidence of separation until November 4, when with a power of 1000 and good seeing there appeared for the first time some evidence of "notching." As soon as observations were begun in Mexico I took occasion to examine this object. It then appeared for the first time actually separated, though still very close. In the subsequent observations the object became easier and easier, until now the star is well separated with a black line between the components, and the division can be seen with comparative ease even if the observer has little experience or the seeing is not the very best. We estimate the seeing on a scale of 10; that at Flagstaff was uniformly rated at 7; here in Mexico it has been rated at 4 and 5. The atmospheric conditions here were certainly not so good as those at Flagstaff.

Under these circumstances I do not hesitate in the belief that the companion has recently passed periastron, and that we have observed it widen out from month to month, until it is now within the reach of moderate sized telescopes. I have, therefore, investigated the general nature of the orbit, and herewith submit an approximate set of elements, which will be sufficiently exact for the use of observers.

The following considerations enable us to derive the essential element of the apparent orbit.

1. The motion since 1895·7, over an arc of 210°, indicates that the period will be very short, probably not far from five years; the observations of Schiaparelli point to a similar conclusion, and hence if we take the angle in 1879·0 to be 197°·5 we may conclude that three revolutions have been performed between that date and 1896; whence we deduce a period of about 5·5 years. All the observations are consistent with such a period except that of Burnham in 1891·97, where the angle appears to be in error about a quadrant. On inquiring of him whether there could be an error in the reduction of the angle, he writes that he does not think there can be an error of a quadrant in the published measure.

We shall at present make no attempt to assign the cause of the discrepancy. The other observations indicate an error of


180°
1895·7
1879·0
1894·6
1883·7
1890·1
1888·1
1892·0
270°
90°
1887·7
1896·7
1896·8
1897·1
1897·2
0°
β 883
0″·0
0″·1
0″·2
Scale

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some kind, and we must reject either the one observation or all the others combined.

Even if all the other observations be discarded there will still be a case of rapid motion, as the angle is now 90°, or 270° different from that recorded in 1891·97.

2. The elements of the orbit are as follows :—

$P = 5{\cdot}5$ years $\quad a = 0''{\cdot}621$

$T = 1896{\cdot}40 \quad \Omega = 20°{\cdot}6$

$e = 0{\cdot}760 \quad i = 82°{\cdot}52$

$\lambda = 273°{\cdot}83$

Apparent orbit :—

Length of major axis	$= 0''{\cdot}67$
Length of minor axis	$= 0''{\cdot}16$
Angle of major axis	$= 19°{\cdot}5$
Angle of periastron	$= 318°{\cdot}0$
Distance of star from centre	$= 0''{\cdot}07$

The apparent orbit shows the general nature of the motion, and indicates very decidedly that the period cannot much surpass 5·5 years, and that the eccentricity and inclination are very high.

Comparison of Computed with Observed Places. β 883.

t	θ_o	θ_c	$\theta_o - \theta_c$	ρ_o	ρ_c	$\rho_o - \rho_c$	N.
1879·00	197°·5	191°·0	+ 6°·5	0″·35	0″·37	−0″·02	1
1887·15	84·7	54·9	+29·8	0·15	0·21	−0·06	3
1888·06	124·4	130·2	− 5·8	0·18	0·15	+0·03	2
1889·14	158·5	179·2	−20·7	0·20	0·31	−0·11	4
1890·14	203·4	195·5	+ 7·9	0·16	0·30	−0·14	3
1891·14	single	22·4	...	...	0·24	...	1
1891·15	„	22·4	...	...	0·24	...	2
1891·97	33·1 ? 123·1	36·1	− 3·0?	0·12	0·30	−0·18	3
1893·07	single	80·1	...	...	0·16	...	1
1894·65	173·5	178·8	− 5·3	0·20	0·31	−0·11	1
1895·15	uncertain	190·9	...	...	0·37	...	1
1895·74	186·4	193·3	− 6·9	0·39	0·35	+0·04	2
1895·74	188·9	193·3	− 4·4	...	0·35	...	1
1896·692	11·0	23·3	−12·3	0·15 ±	0 25	−0·10	2
1896·805	25·1	25·3	− 0·2	0·20 ±	0·31	−0·11	2
1897·073	34·4	29·6	+ 4·8	0·28	0·31	−0·03	2
1897·162	35·5	31·0	+ 4·5	0·25	0·31	−0·06	3
1897·162	36·0	31·0	+ 5·0	0·35	0·31	+0·04	1
1897·192	37 5	31·4	+ 6·1	0·35	0·31	+0·04	2

3. It is now clear that Mr. Burnham's supposition, that the motion from 1879·00 to 1892 amounted to 100°, fell far short of the truth. At that time it must have amounted to about two and one half revolutions. For during the interval since 1892 the companion has swept over an arc of 270°; even if it were admissible to suppose that it is now in the third quadrant instead of the first (indicated by our observations), we should still have a motion of 90° since 1892, which contradicts the hypothesis of slow motion. Supposing that only 90° have been described since 1892, the slow motion hypothesis is contradicted by the observations of Schiaparelli in 1887, 1888, 1889, and by our inability to see the pair separated in 1896 with the 24-inch, whereas the object was easily divided in 1895·7 with a 15½-inch telescope. Also, if the motion is slow the minimum change which can have taken place since 1892 (90°) requires that the orbit should be much extended in the first quadrant, and hence the star would have been wide and easy at the time of Schiaparelli's observations; he actually found it close and difficult and, except in the first case, in the second and third quadrants. It is, therefore, clear that the motion of this system is very rapid, and that no other hypothesis will explain the phenomena.

The results here submitted give only a first approximation to the orbit, and doubtless some improvement of the elements will soon be possible. This remarkable object ought to be followed from month to month during the whole time it is visible. By securing a closely connected series of observations we shall soon be able to render the orbit very exact.

The discovery of an object revolving in a period of 5·5 years is an achievement of some philosophic significance in the history of double star astronomy. In the time of Sir John Herschel the most rapid of known binaries was ζ *Herculis*, with a period of 35 years. Twenty years ago the remarkable object 42 *Comæ Berenices* had reduced the shortest period to about 25 years, and in 1887 δ *Equulei* brought it down to 11·5 years. κ *Pegasi* (β 989) has since been shown to revolve in a similar period.

In β 883 we have for the first time a visible binary with a period fairly approaching those of the spectroscopic binaries recently discovered, and we seem assured that at last a link has been found connecting the two classes of objects. It is probable that other stars will disclose even shorter periods, for there is no reason why there should not be close doubles with periods of a single year or less. It will be an interesting object of future research to fill in the intervening steps between visible binaries with periods of a few years and the spectroscopic binaries revolving in a few days or months.

The more critical inquiry into the motion of close doubles will commend itself to the attention of double star observers with great telescopes, and on the other hand it may be hoped that the study of the relative motion in line of sight of the com-

ponents of binaries like β 883 will be taken up by some of our great observatories equipped with powerful spectroscopic appliances.

Lowell Observatory, City of Mexico:
1897 *March* 12.

Since the above paper was forwarded to the Secretary I have received from Professor Barnard full details of his observations in 1894. These measures are very important, and since they are not all included in the above list, they are here condensed.

t	θ_o	ρ_o	Remarks.
1894·649	173°·5	0″·20	Seeing 4 (scale of 5); the stars are north and south; power, 1500.
1894·668	176·8	0·20	Seeing, 4–5; power, 1500.
1894·671	178·7	0·16	Seeing, 5; power, 1500. Stars very close.

The instrument used was of course the 36-inch refractor.

These measures leave absolutely no doubt of the rapid motion between 1892 and 1894, and are therefore in accordance with the results given in the foregoing paper.

Lowell Observatory, City of Mexico:
1897 *April* 7.

Results of Double-Star Measures with the 8-inch Equatorial at Windsor, New South Wales, in 1896.
By John Tebbutt.

Ref. No.	Star.	Observed Mags.	Approx. Place of Star 1896·0. R.A.	Dec. S.	Fraction of Year.	Position Angle.	No. of Obs.	Distance.	No. of Obs.	Mag. Power.	Eyes.	Hour Angles.		Weight 1 to 5.
			h m	° ′		°		″				h m	h m	
1	*p* Eridani	...	1 36	56 43	·986	223·3	10	7·63	8	300	P	0 46 W	1 40 W	4
2	„	...	„	„	·988	223·6	10	7·77	6	230	R	2 48 W	3 9 W	3
3	„	6, 6	„	„	·999	223·7	10	7·44	8	300	R	2 41 W	3 11 W	3
4	Lacaille 2145	...	6 2	48 27	·986	33·6	10	1 60	5	300	P	2 37 E	2 1 E	4
5	„	...	„	„	·988	33·0	10	2·11	10	230	P	4 11 E	2 53 E	2
6	„	...	„	„	·988	32·1	10	2·05	7	230	P	4 11 E	2 53 E	3
7	„	...	„	„	·999	32·4	9	...	...	300	P	1 6 E	0 43 E	3
8	V Puppis	...	6 36	48 8	·988	319·3	10	13·20	7	230	R	2 54 E	2 25 E	3
9	γ Piscis Vol.	4½, 6	7 10	70 20	·323	299 6	10	13·74	7	230	P	2 17 W	2 53 W	4
10	„	4, 6	„	„	·326	299·2	10	13·68	10	230	P	0 26 W	1 1 W	4
11	γ Centauri	...	12 36	48 23	·323	357·8	10	1·87	10	300	P	1 21 E	0 51 E	4
12	„	...	„	„	·326	358·6	10	...	...	300	P	2 43 E	2 0 E	4
13	„	...	„	„	·326	358·6	10	1 62	10	535				

Ref. No.	Star.	Observed Mags.	Approx. Place of Star 1896·0. R.A. h m	Dec. S. ° ′	Fraction of Year.	Position Angle. °	No. of Obs.	Distance. ″	No. of Obs.	Mag. Power.	Eyes	Hour Angles. h m	h m	Weight 1 to 5
14	,,	...	,,	,,	·329	357·4	10	...	...	300	P	2 10 E	1 33 E	5
15	,,	...	,,	,,	·329	357·6	10	1·73	10	535	P			
16	β Muscæ	...	12 40	67 32	·326	336·2	10	1·17	5	535	R	1 43 E	1 8 E	4, 2
17	,,	...	,,	,,	·329	336·5	10	1·32	6	535	R	1 29 E	0 59 E	5, 4
18	α Centauri	1, 2	14 33	60 24	·320	208·5	10	21·61	7	300	P	2 40 E	2 10 E	4
19	,,	1, 2	,,	,,	·326	208·5	10	21·36	10	535	P	2 49 E	2 10 E	4
20	A Scorpii	4½, 6½	15 47	25 1	·320	279·7	10	2·88	10	230	P	4 39 E	4 8 E	4
21	,,	4½, 7	,,	,,	·323	279·3	10	...	...	300	P	3 49 E	3 9 E	4
22	,,	4½, 7	,,	,,	·323	280·7	10	2·90	7	300	R			
23	,,	4½, 7	,,	,,	·326	279·0	10	2·70	10	300	R	3 0 E	2 24 E	5

Remarks.

In the column headed "Eyes" P denotes that the line joining the observer's eyes was parallel to that joining the components, and R that these lines were at right angles. The column headed "Hour angles" gives the hour angles between which the measures were made, and that headed "Weight" gives the value of each result on a scale of 1 to 5, 1 denoting the worst and 5 the best possible conditions.

The components of 2, 3, and 13 were noted to be equal. The south component of 4 and 7 was certainly the brighter. The primary of 8 was yellowish, and the companion blue.

Windsor, N.S. Wales: 1897 *April* 30.

Nebula H I, 43 *Virginis.* By Professor Kavasjee D. Naegamvala.

The nebula was photographed on three successive nights (April 16, 17, and 18, 1896) with exposures ranging from one hour to two hours in the principal focus of a 16½in. reflector of 122 inches focal length.

The nebula is No. 4,594 in the *New General Catalogue*, and is described as "remarkable, very bright, very large, extremely extended, position-angle 92°, very suddenly much brighter in the middle with a nucleus." It is engraved in the *Philosophical Transactions for* 1833, plate xiv. fig. 50, and also in *Mem.R.A.S.* vol. xxxvi. plate v. fig. 22.

Sir John Herschel, in his "Observations of Nebulæ and Clusters of Stars" (*P. T.* 1833), remarks that "there is a faint diffused oval light all about it," and he is "almost positive that there is a dark interval or stratum separating the nucleus and general mass of the nebula from the light above." Mr. Lassell (*Mem.R.A.S.* xxxvi) with his much larger instrument describes it as a "long spindle-shaped nebula, with a dark band through its entire length." He, however, does not seem to have noticed the nucleus.

Of the two drawings, that of Sir J. Herschel much more resembles the photographs. The photograph taken 1896 April 18, distinctly showed that the nebula was *elliptical* with its plane highly inclined to the line of sight. (This plate was unfortunately destroyed during the final washing.) The nucleus is of a starry character, and much more pronounced than in Sir J. Herschel's drawing.

I hope to submit to the Society a photograph of the nebula at an early date.

May, 1897.

The Effect of the General Illumination of the Sky on the Brightness of Field at the Focus of a Telescope. By F. L. O. Wadsworth.

(*Communicated by the Secretaries.*)

The investigations of Lord Rayleigh have shown that the general illumination of the sky is probably due to light scattered by small (*i.e.* small in comparison with the wave-length of light) particles in our atmosphere, and that the intensity of the light so scattered varies inversely as the fourth power of the wave-length. It seems pretty certain that these particles are present in nearly, if not quite as great quantities, in the upper regions of the atmosphere as in the lower strata, and that they consequently cannot

be of an aqueous origin. The majority of them being at a considerable distance above the surface of the earth, the scattered light which ultimately reaches the eye after repeated changes of direction is of plane wave front, and the general illumination is consequently of the same character as would be produced by a distant uniformly luminous surface of infinite extent. The illumination at any point p, which is the same as that at any other point in the focal field of a telescope, due to such a surface, is, as is well known,

$$I_p = \iint_{\omega} I d\xi d\eta = \iint_{\omega} I dx' dy' \quad \ldots \ldots \ldots \quad (1)$$

where I is the illumination due to a single point s in the surface; $\xi\eta$, the coordinates of the point p, referred to the geometrical image of s, as origin; and conversely x', y', the coordinates of s, referred to the intersection of the optical axis through p, with the surface in which s is situated. The general principle of energy requires that the value of (1) should be equal simply to A, the area of the aperture of the telescope, when the apparent brightness of the surface is unity, or to k A when the apparent brightness is k. A general analytical proof has also been given by Stokes.* It follows, therefore, that the intensity of illumination of the focal field of a telescope, due to the light of the sky, is simply proportional to the area of the telescope aperture, and entirely independent of the focal length of the latter. In the theory of astronomical and astrophysical instruments, particularly those intended for photographic and spectrographic work, in which the greatest possible contrast between the field and the image of the body dealt with is desired, this is a point of great importance, which, strangely enough, has been hitherto entirely overlooked by all writers on the subject whose papers are accessible to me.† Some, indeed, have been led to very erroneous conclusions in regard to the form and size of instrument best adapted to particular purposes by a neglect of this relation between aperture and brightness of field. It has, therefore, seemed to me to be worth while to rediscuss somewhat at length the conditions of maximum efficiency in astro-photo-spectro-graphic work. The discussion as regards the purely astro-photographic side of the question is briefly outlined in the current (July ?) number of *Knowledge*, "On the Conditions which Determine the Limiting Time of Exposure of Photographic Plates in Astronomical Photography," and will be found more fully developed, from a mathematical side, in the next (August) number of the *Astrophysical Journal*, "On the Conditions of Maximum Efficiency in

* *Trans. Roy. Soc. Edin.* vol. xx. p. 317, 1853. See also "Wave Theory," *Enc. Brit.* vol. xxiv. § 11.

† The importance of this point in the case of photographic work is enhanced by the character of the sky illumination, which, owing to its varying as the fourth power of the wave-length, has a much greater effect on the photographic plate than on the eye.

Astro-Photographic Work," in which questions relating to astro-physical work, particularly stellar and nebular spectrography and coronal photography, both during and without an eclipse, are also taken up. Without entering at length into the argument here, the more important conclusions which have been reached may be summed up as follows:—

I. The absolute intensity of the image of a celestial object, and, therefore, the absolute photographic light action (product of intensity by time) for a given time of exposure, will vary, (1) for extended sources as the square of the angular aperture only, (2) for point sources as the product of the square of the angular aperture times the square of the linear aperture.

II. The relative intensity of the image with respect to the field (contrast) for any celestial object not very near the horizon, will depend upon (1) the brightness of the sky at the time; (2) the efficiency of the image-forming lens as regards perfection of figure, nature and curvature of surfaces, &c.; and (3) upon the square of the linear aperture. If the objectives are good, the sky effect (1) and (3) are the most important.

III. For faint extended objects such as nebulæ, irresolvable star clouds, &c., in which we have to deal with the delineation of a surface rather than with individual points, this contrast can only be increased by decreasing the focal length. When the sky effect (1) and (3) is predominant it will vary inversely as the square of the latter quantity.

IV. For point sources the contrast can only be increased by increasing the angular aperture. Under the same conditions as in III, it will vary directly as the square of the angular aperture.

V. It is the degree of contrast, and not size of objective (except in so far as this latter influences the contrast) that determines the limiting magnitude of the faintest object that can be photographed. This limiting magnitude for stars depends therefore only on the angular aperture of the instrument, and for nebulæ only on the focal length.

VI. The time of exposure also depends very largely on the contrast between image and field, and not on the absolute intensity of the former. If the development could be suited in every case to the exposure, the time of the latter necessary to obtain any given degree of detail would vary inversely as the contrast within a wide range of photographic light action.

VII. In the problem of photographing the corona without an eclipse, the general conclusion in III is modified to some extent by the increased brightness and increased whiteness of the sky near the Sun, due probably to the presence of water vapour in the lower strata of our atmosphere. It seems, however, certain that a great advantage will result from using an image-forming lens of very small linear aperture and very short focal length for this purpose. Those who have used pin holes have been right in so far as a small linear aperture is concerned, but wrong in so far as they have placed the plate at a distance from the opening.

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VIII. For nebular spectrographic work the integrating spectrograph (one in which the image-forming or condensing lens is of zero dimensions), is the best possible form for securing a maximum contrast.

IX. In stellar spectrographic as well as in stellar photographic work, the "condensing" (telescope) objective should have the largest possible angular aperture.*

X. As regards the influence of the character of the objective (II (2)) upon the illumination of the field, the refractor seems to have a decided advantage. The angular aperture of the latter should not, however, be greater than 1-5. To photograph the very faintest star (beyond 17th magnitude) a reflector of the largest possible angular aperture, 1-3 or 1-2 if possible, is the only instrument that can be used. For stellar spectrographic work, in which only a small field is required, the reflector of large angular aperture is greatly superior to the refractor.†

Yerkes Observatory:
1897 *June* 3.

A Note on Spider Lines. By F. L. O. Wadsworth, Astrophysicist, Yerkes Observatory.

(*Communicated by the Secretaries.*)

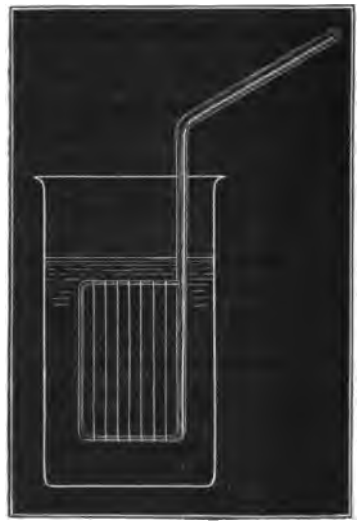
Apropos of the present discussion on the straightness of spider lines—see paper by Professor Turner in the last (April) number of the *Monthly Notices*—it may be well to point out that whether such an effect has ever been observed or not, it would be well to guard against its possible occurrence by using for the cross wires in our instruments something of a more reliable and permanent nature than the usual spider web. This, although very fine and strong, has so many and such grave disadvantages as to make one wonder how it has ever been tolerated as long as it has. Formerly perhaps it might have been said that there was no thoroughly satisfactory substitute; even the finest metal wires prepared by the so-called Wollaston process being too coarse, and silk having the same disadvantages as spider line itself in the way of hygroscopicity and semi-translucency. Now, however, the invention of the quartz fibre by Boys has provided us with something

* In connection with this point see also my paper, "General Conditions respecting the Design of Astronomical Spectroscopes," in the first number of the *Astrophysical Journal*, Jan. 1895, p. 52 (particularly pp. 70–71).

† For other advantages of the reflector see also paper by Professor Hale in a recent number of the *Astrophysical Journal* (Feb. 1897, p. 119), and various papers by the writer in the *Phil. Mag.* (vol. xxxviii. pp. 137 and 337), *Astronomy and Astrophysics* (vol. xiii. p. 835), and the *Astrophysical Journal* (vol. i. p. 232; vol. ii. p. 370; vol. iii. p. 169 [particularly pp. 182 and 183]; vol. iii. p. 347; &c.).

which is not only entirely unaffected by atmospheric changes, but also superior to spider line, and, in fact, to all other known fibres, in strength and fineness. The quartz fibres themselves are transparent, but this difficulty is removed, and the fibres made more easily visible for handling and mounting as well, by silvering them by any of the well-known silvering processes. When properly silvered they are perfectly opaque, even in the most strongly illuminated field.

I do not know who first proposed the use of silvered quartz fibres for this purpose, but their obvious advantages must have suggested their use for this and many similar purposes (such as fine plumb and level lines, &c.) to many others besides myself. I first used them for the cross wires of an observing telescope about five years ago, while a student at Clark University. It is hardly necessary to say that I have continued to use them ever since whenever it was possible to obtain or make them, and I know of many others whose experience has been equally satisfactory. Nevertheless, they do not yet seem to be as generally known and widely used as they ought to be. It is sometimes difficult to obtain sufficiently fine fibres from dealers, at least in this country; but anyone can, after a little practice, make them for himself, the only really essential things being a good oxyhydrogen blow-pipe and a supply of reasonably pure hydrogen (coal gas is very unsatisfactory), and oxygen in pressure tanks. These requisites can now all be readily obtained from any good dealer in projection apparatus. Many plans for "shooting" the fibres have been proposed, but I have never found anything more simple or satisfactory than the original bow and arrow method of Pro-



Frame for silvering quartz fibres.

fessor Boys. See paper "On the Production Properties and Some Suggested Uses of the Finest Fibres," *Phil. Mag.* 1887 June.

For silvering them I prefer Brashear's method (described at length in a paper by the writer, "On Silvering Solutions and Silvering," *Astrophysical Journal*, vol. 1, page 252, 1895 March). To get a good coat it is, however, necessary to clean the fibre very carefully. For this purpose I have found it best to use in succession very hot solutions of strong nitric acid and strong potash, and then wash in several changes of clean distilled water before immersing in the silvering solution. In order to handle the fibres during these operations I have found it convenient to mount them on a small rectangular glass frame with a bent handle, similar to that shown in the figure. The ends of the fibres are secured to the upper and lower bars of the frame by fused (not dissolved) shellac, which resists well the action of the hot acid and alkali. In lifting the frame in and out of the solutions care should be taken to move it vertically up and down, otherwise the fine fibres will be broken by the surface tension of the liquid surface. On such a frame a dozen fibres may be silvered at once, and then set aside for use as desired.

Another great advantage which such silvered fibres would be likely to possess when used in bright wire micrometers, *i.e.* that of perfect and uniform illumination, was pointed out by Professor Burnham in the course of a recent conversation with the writer on this subject. To get the best results in such a case a cylindrical mirror should be placed behind the wire (on the side away from the source of illumination) with its axis parallel to the length of the wire.

Yerkes Observatory:
1897 *May* 29.

Notes on the Reduction of Stellar Photographs.

By Prof. Arthur A. Rambaut, M.A., D.Sc.

All who have closely followed the recent developments in the use of photography as a means of measuring the positions of stars must have been impressed with the great value of the methods proposed and advocated by Professor Turner in the several papers which he has published on the subject.

From the point of view taken up by him—which is in the main that of a partaker in the International Photographic Survey of the Heavens, although many of his results have a wider application and are largely useful in facilitating operations and increasing accuracy whatever the object of research may be—from this point of view it is difficult to see in what way much further simplification in the reduction of the plates is to be introduced.

No method for determining the relative positions on overlapping plates can be more simple or symmetrical than that proposed by him and adopted, I understand, at Greenwich, Oxford, and other places.

The secret of this remarkable simplification lies in the fact of his adhering strictly to rectangular coordinates, and avoiding carefully as long as it is possible the use of the old and time-honoured system of right ascension and declination, which the fact of our inhabiting a rotating body obliges us in the last extremity to use in some form or other when we desire to define the position of a celestial body in space.

I expect, however, that there are many workers in this line, who, like myself, are occupied in taking photographs under conditions different from those considered by Professor Turner, M. Loewy, and others, in connection with the Astrophotographic Catalogue, and who find the methods advocated in the *Bulletin du Comité International Permanent pour l'Exécution Photographique de la Carte du Ciel* are not exactly suitable to their particular requirements.

I have been recently engaged in considering the best mode of reducing the plates taken at Dunsink with our 15-inch reflecting telescope, in which we have a means of adjusting the plate with a fair degree of precision, and of thus keeping it very approximately "squared on" to the axis of the telescope, but the actual R.A. and declination of the point to which the telescope is directed is not known with any considerable degree of accuracy, and the plate is merely inserted in an ordinary slide without any particular care as to its orientation.

For work such as we are engaged upon, in which the objects photographed are scattered in all parts of the sky, the principle of the "rattachment" of plates, recommended by Loewy, Turner, and others, for the Astrographic Catalogue, and the elaborate mode of reduction which the former has founded upon it are clearly inadmissible, and some more applicable method must be sought.

In a case of this sort if we have a number of reference stars distributed fairly symmetrically over the plate so that the lines joining them would form a polygon inside of which lie the object or objects whose position it is desired to ascertain, it is possible to attain an accuracy at least equal to the mean accuracy in the positions of the reference stars, and any inaccuracy introduced by small errors in the adopted positions of the latter will not affect the determination of parallax or proper motion provided that the same set of reference stars is used on each occasion.

In what follows I suppose that the measures do not extend over a space of more than a square degree. This is only one quarter of the space covered by one of the plates of the Astrophotographic Catalogue, but this limitation will enable us to dispense with many of the smaller terms which complicate the reduction, and which only become sensible when distances greater than 2000″ have to be considered, while giving us as

wide a region around the centre of each plate in which to find the reference stars as is recommended for the reduction of the Catalogue plates.

In a case such as I have suggested the advantages of using rectangular coordinates can, I think, be best attained by having recourse at once to a system of what Professor Turner calls "standard" coordinates. These are coordinates referred to the projections of the hour circle and of the great circle at right angles to it passing through the origin.

But under the conditions I have supposed we do not know the R.A. and declination of the origin from which our measures are made on the plate, and if we assume an origin for the standard coordinates we do not know precisely the point on the plate representing it.

We have therefore two systems of rectangular axes, one in a tangent plane to the sphere at a point whose R.A. and declination we assume, and the other, that to which the measures are made, whose position in the plane of the plate is known. And what we require to find is a means of passing from one of these systems to the other.

This is afforded us by a comparison of the coordinates of the reference stars with regard to each of them.

Now let us denote by O the point of the plate which we take as the zero of measurement, while the centre of the plate (C) is defined as the point in which the normal to it from the centre of the objective, or from the centre of curvature of the mirror, cuts the plate. If we take a pair of axes passing through the centre of the sphere parallel to the axes of measurement during the exposure, then these two with the direction of the normal to the plate through C form a system of three mutually rectangular axes. Let the coordinates of the image (S) of a star σ referred to there be x, y, z.

If now we take another system of rectangular axes passing through the centre of the sphere, of which the axes of x and y are parallel to our assumed standard axes, and if these make angles α, β, γ; α', β', γ'; α'', β'', γ'' respectively with the previous system, and if the coordinates of the star σ referred to these be X, Y, Z we have

$$X : Y : Z = x\cos\alpha + y\cos\beta + z\cos\gamma : x\cos\alpha' + y\cos\beta' + z\cos\gamma' : x\cos\alpha'' + y\cos\beta'' + z\cos\gamma''$$

Therefore

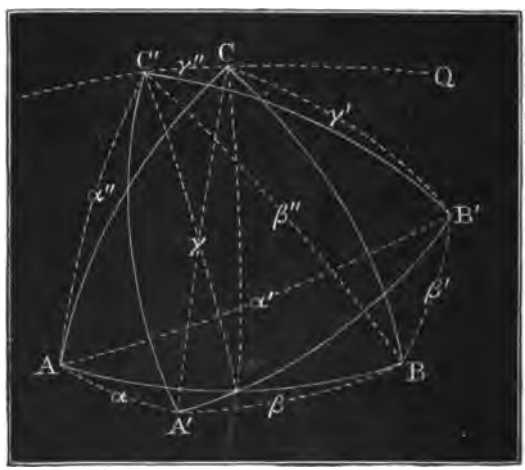
$$\left.\begin{aligned} \frac{X}{Z} &= \frac{\frac{x}{z}\frac{\cos\alpha}{\cos\gamma'} + \frac{y}{z}\frac{\cos\beta}{\cos\gamma'} + \frac{\cos\gamma}{\cos\gamma'}}{\frac{x}{z}\frac{\cos\alpha''}{\cos\gamma''} + \frac{y}{z}\frac{\cos\beta''}{\cos\gamma''} + 1} \\ \text{and} \\ \frac{Y}{Z} &= \frac{\frac{x}{z}\frac{\cos\alpha'}{\cos\gamma'} + \frac{y}{z}\frac{\cos\beta'}{\cos\gamma'} + \frac{\cos\gamma'}{\cos\gamma'}}{\frac{x}{z}\frac{\cos\alpha''}{\cos\gamma''} + \frac{y}{z}\frac{\cos\beta''}{\cos\gamma''} + 1} \end{aligned}\right\} \quad \ldots\ldots\ (1)$$

But $-Z$ is the radius of the sphere while $-z$ is the focal length of the telescope. Hence $-\frac{X}{Z}, -\frac{Y}{Z}$ are the standard coordinates (ξ and η) of the star expressed in radians, while $-\frac{x}{z}, -\frac{y}{z}$ are the coordinates of the star's image on the plate expressed in the same manner. Now we may put $-Z$ equal to unity, and if we denote $-\frac{1}{z}$ by λ (where λ is the value of a unit of the screw or scale with which the measures are made) we find

$$\left.\begin{aligned}\xi &= \frac{\lambda(ax+by)+c}{1-\lambda(kx+ly)}\\ \eta &= \frac{\lambda(dx+ey)+f}{1-\lambda(kx+ly)}\end{aligned}\right\} \quad \ldots\ldots\ldots \quad (7)$$

These are the expressions found by Professor Turner in his first paper on this subject (*Monthly Notices*, liv. 1) except that he supposes $\lambda=1$, but this method of deducing them has the distinct advantage of showing plainly the geometrical meaning of each of the quantities involved.

For instance, from equations (1) we can exhibit in a very symmetrical manner the relations between the coefficients a, b, c, &c., deduced by Professor Turner in his paper in the *Monthly Notices*, vol. lvii. 3. For this purpose we have recourse to the accompanying figure in which A, B, C, A′, B′, C′ are the points in which the two sets of axes intersect the sphere.



Then

$$AA' = \alpha, \quad BA' = \beta, \quad CA' = \gamma$$
$$AB' = \alpha', \quad BB' = \beta', \quad CB' = \gamma'$$

and

$$AC' = \alpha'', \quad BC' = \beta'', \quad CC' = \gamma''$$

and since C and C′ are the poles of AB and A′B′ respectively, therefore the angle APA′=γ''. Also the angle QCA is Professor Turner's α which I denote by p, and QC′A′ is Professor Turner's β which I denote by q.

Then since P is the pole of CC′ it follows that

$$\mathrm{AP}\,(=\mathrm{ACP})=p-\frac{\pi}{2},\ \mathrm{PB}=\pi-p$$

and

$$\mathrm{A'P}\,(=\mathrm{A'C'P})=q-\frac{\pi}{2},\ \mathrm{PB'}=\pi-q$$

Hence it follows at once that

$$\begin{aligned}
\cos\alpha &= \sin p\sin q+\cos p\cos q\cos\gamma''\\
\cos\beta &= -\cos p\sin q+\sin p\cos q\cos\gamma''\\
\cos\gamma &= \cos q\sin\gamma''\\
\cos\alpha' &= -\sin p\cos q+\cos p\sin q\cos\gamma''\\
\cos\beta' &= \cos p\cos q+\sin p\sin q\cos\gamma''\\
\cos\gamma' &= \sin q\sin\gamma''\\
\cos\alpha'' &= -\cos p\sin\gamma''\\
\cos\beta'' &= -\sin p\sin\gamma''
\end{aligned}$$

Hence,

$$\left.\begin{aligned}
a &= \frac{\cos\alpha}{\cos\gamma''} = \cos p\cos q+\sin p\sin q\sec\gamma''\\
b &= \frac{\cos\beta}{\cos\gamma''} = \sin p\cos q-\cos p\sin q\sec\gamma''\\
c &= -\frac{\cos\gamma}{\cos\gamma''} = -\cos q\tan\gamma''\\
d &= \frac{\cos\alpha'}{\cos\gamma''} = \cos p\sin q-\sin p\cos q\sec\gamma''\\
e &= \frac{\cos\beta'}{\cos\gamma''} = \sin p\sin q+\cos p\cos q\sec\gamma''\\
f &= -\frac{\cos\gamma'}{\cos\gamma''} = -\sin q\tan\gamma''\\
k &= \frac{\cos\alpha''}{\cos\gamma''} = -\cos p\tan\gamma''\\
l &= \frac{\cos\beta''}{\cos\gamma''} = -\sin p\tan\gamma''
\end{aligned}\right\}\quad\ldots\ldots\ (3)$$

These are the relations found by Professor Turner. From the values of these quantities expressed in terms of the direction-cosines, we see that

$$a^2+b^2+c^2=d^2+e^2+f^2=1+k^2+l^2=\sec^2\gamma'',$$

relations which afford an important check on the accuracy of the computation.

From these equations, again, it appears that

$$c-k=(\cos p-\cos q)\tan\gamma''=-2\sin\tfrac{1}{2}(p-q)\sin\tfrac{1}{2}(p+q)\tan\gamma''$$

and

$$f-l=(\sin p-\sin q)\tan\gamma''=\quad 2\sin\tfrac{1}{2}(p-q)\cos\tfrac{1}{2}(p+q)\tan\gamma''$$

But $p-q$ can never exceed a, so that the differences $c-k$ and $f-l$ are of the order $a\gamma''$, and hence to a first approximation may be neglected.

If we denote by x', y' the coordinates of the image S of a star σ, measured parallel to rectangular axes, passing through any point O on the plate, and if x_0, y_0 are the coordinates of the centre C referred to the same axes, then the coordinates of S referred to parallel axes through C are $x=x'-x_0$, $y=y'-y_0$.

For the origin of standard coordinates, we may take any point of the sphere whatever, the right ascension and declination of which we denote by A and D, and we shall have equations (2) connecting ξ, η, with x, y.

But if γ'' is a small quantity, *i.e.*, if the centre of the plate is close to the origin of standard coordinates—a condition which it is easy to fulfil—these expressions may be very much simplified.

For if we substitute from equations (3), neglecting powers of γ'' and λx, λy, beyond the third, and denoting the angle $g-p$ by ϕ, we find,

$$\xi=\frac{\lambda(x\cos\phi-y\sin\phi)+\cos q\,.\,\gamma''+\frac{1}{2}\sin q\,.\,\lambda(x\sin p-y\cos p)\gamma''^2+\frac{1}{3}\cos q\,.\,\gamma''^3}{1+\lambda(x\cos p+y\sin p)(\gamma''+\frac{1}{3}\gamma''^3)}.$$

Now, if γ'' does not exceed $100''$, we may reject its cube and terms of the first order in x, y, when multiplied by its square, and of the second order multiplied by γ''.

To this order of approximation we find simply

$$\xi=\lambda(x\cos\phi-y\sin\phi)+\cos q\,.\,\gamma'',$$

while in a similar manner we obtain

$$\eta=\lambda(x\sin\phi+y\cos\phi)+\sin q\,.\,\gamma''.$$

Hence we see that $\cos q\,.\,\gamma''$ and $\sin q\,.\,\gamma''$ are the standard coordinates of the centre with regard to (A, D). Denoting them by ξ_0, η_0, we have finally,

$$\left.\begin{aligned}\xi-\xi_0&=\lambda[(x'-x_0)\cos\phi-(y'-y_0)\sin\phi]\\ \eta-\eta_0&=\lambda[(x'-x_0)\sin\phi+(y'-y_0)\cos\phi]\end{aligned}\right\}\quad\ldots\ldots\quad(4)$$

These are the ordinary formulæ of transformation from one pair of rectangular axes to another, and their applicability

depends on the fact that the assumption we have made as to the magnitude of γ'' is equivalent to assuming that the centre of the plate is so near the origin of standard coordinates, that the straight lines into which the latter project are sensibly at right angles to each other within the limits of the plate.

By means of the equations (4), we can, from the standard coordinates of two known stars, determine the values of λ and ϕ, whatever their magnitude may be, but in practice ϕ will always be a small angle, and λ will differ but little from unity. In this case assume

$$\lambda \cos \phi = 1 + \mu \cos \nu = 1 + P$$
$$\lambda \sin \phi = \quad \mu \sin \nu = Q,$$

where P and Q are both small quantities. Then denoting by the subscript figures 1 and 2, the coordinates relating to the two reference stars, we have

$$(\xi_1 - \xi_2) - (x'_1 - x'_2) = \mu \cos \nu (x'_1 - x'_2) - \mu \sin \nu (y'_1 - y'_2)$$
$$(\eta_1 - \eta_2) - (y'_1 - y'_2) = \mu \sin \nu (x'_1 - x'_2) + \mu \cos \nu (y'_1 - y'_2).$$

Then assuming

$$\tan \psi_{12} = \frac{(\eta_1 - \eta_2) - (y'_1 - y'_2)}{(\xi_1 - \xi_2) - (x'_1 - x'_2)} \text{ and } \tan \theta_{12} = \frac{y'_1 - y'_2}{x'_1 - x'_2}$$

we have $\tan \psi_{12} = \tan (\nu + \theta_{12})$ or $\nu = \psi_{12} - \theta_{12}$.

Also,

$$\sqrt{[(\xi_1 - \xi_2) - (x'_1 - x'_2)]^2 + [(\eta_1 - \eta_2) - (y'_1 - y'_2)]^2} = \mu \sqrt{(x'_1 - x'_2)^2 + (y'_1 - y'_2)^2},$$

whence

$$\mu = \frac{(\xi_1 - \xi_2) - (x'_1 - x'_2)}{x'_1 - x'_2} \cdot \frac{\cos \theta_{12}}{\cos \psi_{12}} = \frac{(\eta_1 - \eta_2) - (y'_1 - y'_2)}{y'_1 - y'_2} \frac{\sin \theta_{12}}{\sin \psi_{12}}.$$

Equations (4) may be written

$$\xi - x' - Px' + Qy' = \xi_0 - x_0 - Px_0 + Qy_0 = \bar{\xi}$$

and

$$\eta - y' - Qx' - Py' = \eta_0 - y_0 - Qx_0 - Py_0 = \bar{\eta}.$$

Substituting the values of P and Q in the left hand members, we find the values of $\bar{\xi}$, $\bar{\eta}$, which are the coordinates of O, referred to the standard axes through (A, D).

If the values of P and Q, as derived from different pairs of reference stars, are sensibly the same, so that the various values of $\bar{\xi}$ and $\bar{\eta}$ do not differ by more than the probable error in the coordinates of the stars will account for, we need go no further, but may assume P, Q, $\bar{\xi}$, $\bar{\eta}$ as the constants of the plate.

If, however, large differences occur in the values of P, Q, $\bar{\xi}$, $\bar{\eta}$, it follows that γ'' is not as small a quantity as is contemplated above, and it will be necessary to transform the standard axes to a point more nearly represented by the centre of the plate.

Of course, the quantities ξ, η, $\bar{\xi}$, $\bar{\eta}$ are *apparent* coordinates, and in deducing them from the known declinations and right ascension, the effects of refraction and aberration must be applied before they are compared with the measures.

The true values of these quantities are found from the formulæ

$$\left.\begin{aligned} \xi &= \frac{\cos\delta \sin(\alpha - A)}{\sin\delta \sin D + \cos\delta \cos D \cos(\alpha - A)} \\ \text{and} \\ \eta &= \frac{\sin\delta \cos D - \cos\delta \sin D \cos(\alpha - A)}{\sin\delta \sin D + \cos\delta \cos D \cos(\alpha - A)} \end{aligned}\right\} \quad \ldots\ldots (5)$$

α and δ being the right ascension and declination of the star (compare Ball and Rambaut "On the Relative Positions of 223 Stars in the Cluster χ Persei." *Transactions of the Royal Irish Academy*, vol. xxx. pt. 4, p. 235).

These are the same expressions as those given by Professor Turner in the *Monthly Notices*, vol. liv., 1, p. 13.

In most cases the approximate formulæ deduced from these will be found more convenient. These are, denoting $\alpha - A$ and $\delta - D$ by $\Delta\alpha$ and $\Delta\delta$ respectively,

$$\xi = \cos D \,.\, \Delta\alpha - \sin 1'' \,.\, \sin D \,.\, \Delta\alpha \,.\, \Delta\delta - \frac{1}{2}\sin^2 1'' \,.\, \cos D \,.\, \left(\frac{1}{3} - \cos^2 D\right) \,.\, \Delta\alpha^3,$$

and

$$\eta = \Delta\delta + \frac{1}{4}\sin 1'' \,.\, \sin 2D \,.\, \Delta\alpha^2 + \frac{1}{3}\sin^2 1'' \,.\, \Delta\delta^2 + \frac{1}{2}\sin^2 1'' \,.\, \cos 2D \,.\, \Delta\alpha^2 \,.\, \Delta\delta.$$

For computing the coefficient of $\Delta\alpha^3$ in the first of these the following table for Log. $(\frac{1}{3} - \cos^2 D)$ is useful, three places of decimals being amply sufficient for any cases likely to occur in practice.

Table for Log $\left(\frac{1}{3} - \cos^2 D\right)$.

D.	Log $\left(\frac{1}{3} - \cos^2 D\right)$.		D.	Log $\left(\frac{1}{3} - \cos^2 D\right)$.		D.	Log $\left(\frac{1}{3} - \cos^2 D\right)$.		D.	Log $\left(\frac{1}{3} - \cos^2 D\right)$.	
°			°			°			°		
0	−9·824	0	23	−9·711	11	45	−9·222	48	68	+9·286	25
1	·824	1	24	·700	12	46	·174	54	69	·311	24
2	·823	1	25	·688	12	47	·120	62	70	·335	22
3	·822	1	26	·676	13	48	−9·058	71	71	·357	19
4	·821	2	27	·663	14	49	−8·987	85	72	·376	18
5	·819	2	28	·649	14	50	·902	105	73	·394	16
6	·817	3	29	·635	15	51	·797	137	74	·410	15
7	·814	3	30	·620	17	52	·660	201	75	·425	14
8	·811	3	31	·603	17	53	·459	376	76	·439	12
9	·808	4	32	·586	18	54	−8·083		77	·451	11
10	·804	5	33	·568	19	55	+7·633	681	78	·462	11
11	·799	4	34	·549	20	56	8·314	251	79	·473	9
12	·795	5	35	·529	22	57	·565	155	80	·482	8
13	·790	6	36	·507	23	58	·720	113	81	·490	7
14	·784	6	37	·484	25	59	·833	88	82	·497	6
15	·778	7	38	·459	27	60	·921	72	83	·503	5
16	·771	7	39	·432	28	61	8·993	60	84	·508	5
17	·764	7	40	·404	31	62	9·053	51	85	·513	4
18	·757	8	41	·373	33	63	·104	46	86	·517	2
19	·749	9	42	·340	36	64	·150	39	87	·519	2
20	·740	9	43	·304	39	65	·189	36	88	·521	1
21	·731	10	44	·265	43	66	·225	32	89	·522	1
22	·721	10	45	·222		67	·257	29	90	·523	
23	·711					68	·286				

The corresponding expressions for deducing $\Delta\alpha$ and $\Delta\delta$ from the values of ξ and η, are given in the above mentioned memoir by Ball and Rambaut, and are

$$\left.\begin{aligned} \Delta\alpha \cos D &= \xi + \sin 1'' \tan D \,.\, \xi\eta - \tfrac{1}{3}\sin^2 1'' \sec^2 D \,.\, \xi^3 + \sin^2 1'' \tan^2 D \,.\, \xi\eta^2 \\ \text{and} \\ \Delta\delta &= \eta - \tfrac{1}{2}\sin 1'' \tan D \,.\, \xi^2 - \tfrac{1}{2}\sin^2 1'' \sec^2 D \,.\, \xi^2\eta - \tfrac{1}{3}\sin^2 1'' \,.\, \eta^3. \end{aligned}\right\} \quad (6)$$

These formulæ contain all the terms which it is necessary to consider, provided that ξ and η do not exceed 2000″, and that D is less than 75°. This will include the vast majority of cases likely to occur in practice, but if it be desired to extend the measures much beyond half a degree from the centre and for

regions nearer the pole, higher terms must be considered or the exact formulæ employed.

The terms of the fourth order are given in a paper by Östen Bergstand, "Sur la Réduction des Mesures Micrométriques des Clichés Photographiques Stellaires" (*Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar*, 1896, No. 7), while those of the fourth and fifth orders will be found in a paper by Dr. Jacoby, on "The Reduction of Stellar Photographs," contained in the *Contributions from the Observatory of Columbia University, New York*, No. 10.

In the latter paper the author prefers to employ the quantity $\frac{1}{15}\xi$ sec D instead of ξ, which renders his formulæ somewhat cumbersome and more unattractive than is necessary, but they can be easily transformed so as to express $\Delta\alpha$ and $\Delta\delta$ in terms of ξ and η directly.

Refraction.

In the majority of cases likely to occur in practice the formulæ for the refraction, deduced by Professor Turner in his paper published in the *Monthly Notices*, vol. liv. No. 1, containing only terms of the first order in ξ and η, will be amply sufficient. For the limits at which the terms of the second order and those depending on $\frac{d\beta_0}{d\zeta}$ and $\beta_0{}^2$ become appreciable, compare a paper by the present author entitled "The Corrections for Refraction to Measures of Stellar Photographs," in the *Astronomische Nachrichten*, No. 3125.*

Professor Turner's formulæ are

$$d\xi = -\beta_0 (1+X^2)\,\xi - \beta_0 XY \,.\, \eta$$

and

$$d\eta = -\beta_0 XY \,.\, \xi - \beta_0 (1+Y^2) \,.\, \eta$$

in which X, Y denote the coordinates of the projection of the zenith on the plane containing the standard axis, and β_0 is the coefficient of refraction, corresponding to the point where these standard axes intersect at the middle of the exposure.

The simplicity and symmetry of these expressions must recommend them to every one who is familiar with the more cumbrous formulæ, which become necessary when the relative positions of stars are defined by means of their differences of R.A. and declination.

But although, as they stand, they are all that could be desired from an analytical point of view, yet as Professor Turner leaves them they are not as convenient as they might be for numerical computation.

* See also Kapteyn, *Bulletin du Comité International Permanent*, etc., Tome III., and Bergstrand, *Öfversigt af Kongl. Vetenskaps Akademiens Förhandlingar*, 1897, No. 2.

They may, however, be very readily transformed into a more convenient form. For since in the case of the zenith—for which $a=\theta$, the sidereal time at the middle of the exposure, and $\delta=\phi$—we have, see equations (5).

$$X=\frac{\cos\phi\sin(\theta-A)}{\sin\phi\sin D+\cos\phi\cos D\cos(\theta-A)}$$

and

$$Y=\frac{\sin\phi\cos D-\cos\phi\sin D\cos(\theta-A)}{\sin\phi\sin D+\cos\phi\cos D\cos(\theta-A)}$$

if we take m and n such that

$$\cos n=\cos\phi\sin(\theta-A)$$

$$\sin n\sin m=\cos\phi\cos(\theta-A)$$

and

$$\sin n\cos m=\sin\phi$$

we find

$$X=\frac{\cos n}{\sin n\sin(m+D)}\text{ and }Y=\frac{\sin n\cos(m+D)}{\sin n\sin(m+D)}.$$

Hence,

$$1+X^2=\frac{1-\sin^2 n\cos^2(m+D)}{\sin^2 n\sin^2(m+D)}$$

$$XY=\frac{\sin n\cos n\cos(m+D)}{\sin^2 n\sin^2(m+D)}$$

$$1+Y^2=\frac{\sin^2 n}{\sin^2 n\sin^2(m+D)}$$

But if ζ denote the zenith distance

$$\cos\zeta=\sin n\sin(m+D),$$

—a quantity we have to compute in order to obtain β_0—and if we take

$$\sin n\cos(m+D)=\cos n'$$

we have

$$1+X^2=\frac{\sin^2 n'}{\cos^2\zeta},\quad XY=\frac{\cos n'\cos n}{\cos^2\zeta},\quad 1+Y^2=\frac{\sin^2 n}{\cos^2\zeta}.$$

But m and n, given by the equations

$$\tan m=\cot\phi\cos(\theta-A)$$

and

$$\cot n=\sin m\tan(\theta-A),$$

are the quantities ordinarily used for computing refraction and parallactic angle and are taken directly, with the hour angle as argument, from tables which should be computed for each observatory.

We have then merely to compute

$$\cos \zeta = \sin n \sin (m + \mathrm{D}),$$

whence we find ζ, and therefore β_0, and

$$\cos n' = \sin n \cos (m + \mathrm{D})$$

whence we find sin n' and the refraction formulæ as applied to standard rectangular coordinates become simply

$$d\xi = -\frac{\beta_0}{\cos^2 \zeta}[\sin^2 n' \,.\, \xi + \cos n' \cos n \,.\, \eta]$$

and

$$d\eta = -\frac{\beta_0}{\cos^2 \zeta}[\cos n' \cos n \,.\, \xi + \sin^2 n \,.\, \eta],$$

while equations of the same form, but with a different value of β_0, will give the correction to the apparent ξ and η as deduced from the measures to reduce them to true standard coordinates before transforming into $\Delta\alpha$ and $\Delta\delta$ by means of equations (6).

Aberration.

In the paper referred to above, Professor Turner finds for the effect of aberration the still simpler formulæ

$$d\xi = -\frac{\gamma_0}{\sqrt{1 + \mathrm{X}^2 + \mathrm{Y}^2}} \,.\, \xi \qquad \text{and} \qquad d\eta = -\frac{\gamma_0}{\sqrt{1 + \mathrm{X}^2 + \mathrm{Y}^2}} \,.\, \eta$$

in which γ_0 is the constant of aberration, and (X, Y) is the projection of the "Earth's Way" on the plane of the plate.

As in the case of the refraction formulæ, these expressions may be readily transformed so as to be more convenient for numerical computation.

By the use of Bessel's Day Numbers from the Ephemeris combined with the "Tables for facilitating the Computation of Star Constants," compiled by the late Dr. Stone, the computation of this correction assumes an exceedingly simple form.

For we have

$$\frac{1}{\sqrt{1 + \mathrm{X}^2 + \mathrm{Y}^2}} = \cos \theta_0$$

where θ_0 denotes the angle between the "Earth's Way" and the point of the sky represented by the centre of the plate.

Hence,

$$\frac{-\gamma_0}{\sqrt{1 + \mathrm{X}^2 + \mathrm{Y}^2}} = -\gamma_0 \cos \theta_0 = -\gamma_0[\sin \bar{\delta} \sin \mathrm{D} + \cos \bar{\delta} \cos \mathrm{D} \cos (\bar{\alpha} - \mathrm{A})]$$

in which $\bar{\alpha}$ and $\bar{\delta}$ denote the R.A. and declination of the "Earth's

Way."[1] But, $\odot$ denoting the Sun's longitude and ϵ the obliquity of the ecliptic, we have

$$\cos \bar{\alpha} \cos \bar{\delta} = \sin \odot$$
$$\sin \bar{\alpha} \cos \bar{\delta} = -\cos \odot \cos \epsilon$$
$$\sin \bar{\delta} = -\cos \odot \sin \epsilon$$

Hence,

$$-\gamma_0 \cos \theta_0 = \gamma_0[\cos \odot \sin \epsilon \sin D - \sin \odot \cos D \cos A + \cos \odot \cos \epsilon \cos D \sin A].$$

Writing D′ for $\frac{\pi}{2} - D$ this becomes

$$-\gamma_0 \cos \theta_0 = -\gamma_0[\cos \odot \cos \epsilon \{-\cos D' \tan \epsilon - \sin D' \sin A\} + \sin \odot (-\sin D' \cos A)]$$

But

$$\left.\begin{aligned} -\gamma_0 \cos \odot \cos \epsilon &= A \\ -\gamma_0 \sin \odot \quad\ &= B \end{aligned}\right\} \text{from the Ephemeris}$$

And—without having regard to signs—

$$\sin D' \sin A = a^1, \cos D' \tan \epsilon = sa^1, \text{ and } \sin D' \cos A = b^1,$$

a^1, sa^1, b^1 being the quantities denoted by the same symbols in Dr. Stone's tables corresponding to the declination D′.

We thus find that

$$d\xi = \{A(a^1 + sa^1) + B.b^1\} \sin 1''. \quad \xi$$

with a similar expression for $d\eta$.

With regard to the signs of a^1, sa^1, and b^1, it is easy to see that, adopting the convention that ξ increases in the direction of increasing R.A. and η in that of increasing declination, they may be taken from the following table :—

Signs of the Constants.

North of Equator.			R.A.	South of Equator.		
a^1.	sa^1.	b^1.	h h	a^1.	sa^1.	b^1.
−	−	+	0 to 6	−	+	+
−	−	−	6 „ 12	−	+	−
+	−	−	12 „ 18	+	+	−
+	−	+	18 „ 24	+	+	+

It is not necessary to consider the corrections for Precession and Nutation. For since these are merely changes affecting the positions of the circles from which R.A. and Declination are measured, and have no effect on the relative positions of the stars themselves, they need not be taken into account until we convert the measured rectangular coordinates into differences of R.A. and declination, and then the corrections can best be computed by means of the ordinary tables.

The only remaining disturbance affecting the position of a star which it is necessary to consider is the annual displacement due to

Parallax.

This may be at once deduced from the formulæ for the aberration given by Professor Turner in note iii of his paper in the *Monthly Notices*, vol. liv. No. 1. If we write π for γ_0 (π being the annual parallax), and let X, Y be the coordinates of the projection of the Sun on the plate, then the parallactic displacement is

$$d\xi = \pi \frac{X - \xi}{\sqrt{1 + X^2 + Y^2}}$$

and

$$d\eta = \pi \frac{Y - \eta}{\sqrt{1 + X^2 + Y^2}}$$

in which the eccentricity of the Earth's orbit is neglected.

In these expressions we may reject ξ and η and we get as the effect of parallax

$$d\xi = \frac{\pi X}{\sqrt{1 + X^2 + Y^2}}$$

and

$$d\eta = \frac{\pi Y}{\sqrt{1 + X^2 + Y^2}}.$$

Now

$$\frac{1}{\sqrt{1 + X^2 + Y^2}} = \cos \theta_0$$

θ_0 being in this case the angle between the direction of the Sun and that of the centre of the plate. Hence, α and δ being the Sun's R A. and declination

$$\frac{1}{\sqrt{1 + X^2 + Y^2}} = \sin \delta \sin D + \cos \delta \cos D \cos (\alpha - A)$$

But

$$X = \frac{\cos \delta \sin (\alpha - A)}{\sin \delta \sin D + \cos \delta \cos D \cos (\alpha - A)}$$

and

$$Y = \frac{\sin \delta \cos D - \cos \delta \sin D \cos (\alpha - A)}{\sin \delta \sin D + \cos \delta \cos D \cos (\alpha - A)}$$

Hence we have simply

$$d\xi = \pi \cos \delta \sin (\alpha - A)$$

and

$$d\eta = \pi (\sin \delta \cos D + \cos \delta \sin D \cos [\alpha - A])$$

or, substituting for α and δ in terms of the Sun's longitude and the obliquity of the ecliptic,

$$d\zeta = -\pi(\cos \odot \sin A - \sin \odot \cos \epsilon \cos A)$$

and

$$d\eta = -\pi(\cos \epsilon \sin A \sin D - \sin \epsilon \cos D) \sin \odot - \pi \cos \odot \sin D \cos A$$

in which $d\eta$ is the well known expression for the annual parallax in declination, while $d\xi$ is the parallax in R.A. multiplied by cos D.

Dunsink Observatory, Co. Dublin:
1897 *May* 28.

Photographic Observations of Comet b 1896.

By Professor Arthur A. Rambaut, M.A., Sc.D.

On the nights of 1896 April 29 and 30, May 8 and 11, photographs were taken of Comet *b* 1896 with the 15-inch reflecting telescope of the Dunsink Observatory. After that date, owing to increasing twilight and diminishing brightness of the comet, it could not be found in the 5-inch guiding telescope.

An exposure of ten minutes was given on each occasion, and except in the case of plate *c* on April 30 the movement was adjusted to sidereal rate, and the image of the comet accordingly appears as an elongated patch with ill-defined edges.

The middle point of the axis of this patch was taken as the position of the comet corresponding to the mean time of exposure.

The measures were made in the Troughton and Simms microscope, described in *Transactions of the Royal Irish Academy*, vol. xxx. part iv.

The microscope is provided with two screws, very approximately at right angles to each other, and readings were taken on both screws simultaneously.

The plate was then turned through exactly 90° by the position circle, and another set of measures taken. We thus obtained the rectangular coordinates independently on each screw, and these were separately reduced by the formulæ given in the preceding paper, the mean of the two being taken as the position of the comet given in the table below.

There is not the material for determining the probable error of these positions in the usual way, but an estimate of their precision may be gathered from the following results.

From the measures of +51°, 686 on plate *b*, which were

made at the same time as the others, but were not used in the reduction, I find

+51°, 686.	R.A. 1896·0.	Decl. 1896·0.
	h m s	° ′ ″
First Exposure	3 2 54·92	+51 58 30″8
Second Exposure	54·89	31·1

Compare No. 12 in the list of comparison stars below.

On plate *e*, too, the position of +65°, 217 was measured simultaneously with that of the comet, with the following results :—

+65°, 217.	R.A. 1896·0.	Decl. 1896·0.
	h m s	° ′ ″
First Exposure	1 51 12·62	+65 59 8·8
Second Exposure	12·60	8·6

It only remains to add that the position of the comet being by the mode of reduction referred to the mean positions of the stars for the beginning of the year, I have not thought it necessary to give its apparent R.A. and decl. as is usually done.

Observations of Comet b 1896.

Date.	Plate.	G.M.T.	Local Sidereal Time.	Mean R.A. of Comet.	Log ($\rho \times \Delta$).	Mean Decl. of Comet.	Log ($q \times \Delta$).	Reference Stars.
1896.		h m s	h m s	h m s		° ′ ″		
April 29	*a*	10 10 25	12 18 30	3 6 1·90	−9·5615	+50 0 47·9	−0·8761	14, 15, 16, 17.
30	*b*	10 9 35	12 21 36	3 1 9·59	−9·5616	+51 53 54·3	−0·8759	9, 10, 11, 13.
	b	10 23 48	12 35 51	3 1 6·70	−9·5272	+51 54 54·7	−0·8849	9, 10, 11, 13.
	c	10 38 56	12 51 2	3 1 5·72	−9·4853	+51 56 7·3	−0·8936	9, 10, 11, 12.
May 8	*d*	13 20 24	16 4 29	2 12 12·44	+9·5608	+63 2 31·0	−0·8648	5, 6, 7.
	d	13 34 54	16 19 1	2 12 8·38	+9·6094	+63 2 53·0	−0·8558	6, 7, 8.
11	*e*	12 47 31	15 43 20	1 51 30·25	+9·5999	+65 36 7·5	−0·8534	1, 2, 3, 4.
	e	13 2 11	15 58 3	1 51 26·09	+9·6489	+65 36 35·1	−0·8440	1, 2, 3, 4.

On plates *b*, *d* and *e* two exposures were made, and each exposure reduced separately.

In the case of *c*, the comet itself was kept on the cross-wires, and the stars allowed to trail on the plate. In the other cases, the guiding was done by the aid of one of the comparison stars.

On each occasion the comet appeared sensibly circular, with slight condensation towards the centre.

In the computation of $\mathrm{Log}(p \times \Delta)$ and $\mathrm{Log}(q \times \Delta)$ the adopted value of Sun's mean horizontal parallax is 8″·80.

The meridian-circle observations of the comparison stars were made by Mr. Chas. Martin.

Adopted Places of Comparison Stars, as determined by observations with the Meridian Circle at Dunsink.

No.	B. D.	Mag.	Mean R.A. 1896·0.	Mean Decl. 1896·0.	No. of Obs.	
	°		h m s	° ′ ″		
1	+65, 214	9·5	1 49 2·96	+65 15 44·1	1	
2	+65, 216	8·6	1 50 7·23	+65 56 52·2	2	
3	+65, 218	9·4	1 53 22·11	+66 0 41·2	2	
4	+65, 219	9·5	1 53 47·78	+65 12 52·5	2	
5	+62, 369	7·0	2 8 7·14	+62 45 2·5	2	
6	+63, 319	9·3	2 11 49·52	+63 11 56·8	2	
7	+62, 379	9·0	2 12 40·83	+62 52 19·2	2	
8	+63, 327	8·6	2 15 35·77	+63 15 13·2	2	
9	+51, 678	8·8	3 0 1·08	+51 55 47·8	2	
10	+51, 680	9·4	3 0 29·83	+52 2 53·3	2	
11	+51, 683	9·0	3 1 37·09	+51 42 41·3	2	
12	+51, 686	9·1	3 2 55·03	+51 58 30·9	1	
13	+51, 689	7·3	3 4 13·03	+51 46 8·5	2	
14	+49, 871	8·3	3 4 49·76	+49 52 10·4	2	
15	+49, 873	9·2	3 5 46·24	+50 3 44·7	2	
16	+49, 877	8·7	3 6 41·04	+49 59 23·4	1	
17	+49, 885	9·0	3 8 9·13	+49 43 38·3	2	S.p. of two.

Dunsink Observatory, Co. Dublin:
1897 *May* 28.

Elements of Comet Perrine (f.) 1896 November 2.

By C. J. Merfield.

The following elements are based on observations taken by Mr. John Tebbutt, of Windsor, N.S.W., and kindly communicated to the writer some few days ago.

The selected places, after reducing the time to the meridian

of Greenwich and correcting for aberration, also applying the parallax corrections to α and δ, are as follows :—

	t	α	δ
	d	h m s	° ′ ″
Mar.	5·24871	19 45 0·19	−31 31 58·78
	10·25059	19 42 47·56	−35 22 55·29
	15·24568	19 39 16·54	−39 59 8·32

Adopting the ecliptic as the fundamental plane, these places referred to the mean equinox of 1897 are

Day of year 1897.	λ	β
	° ′ ″	° ′ ″
63·24871	292 30 56·62	−10 6 37·82
68·25059	291 21 2·65	−13 48 56·77
73·24568	289 47 29·75	−18 13 26·36

In the computation the complete expression for the ratio M of the curtate distances for the first and third observations was employed, the radii vectores and anomalies of the comet for the three fundamental positions being derived from the elements by Dr. Knopf, published in the *Astronomische Nachrichten* 3394. The value of log. M thus derived being 9·9093881, this required no correction after the calculation was completed, the various checks being satisfied. The logarithm of the curtate distance for the first observation being 0·1404402.

These values gave the following system of parabolic elements :—

$T = 1897$ Feb. 8·168615 Greenwich M.T.

$$\left.\begin{aligned} \omega &= 172^\circ\ 25'\ 1''\cdot14 \\ \Omega &= 86\ 29\ 10\cdot82 \\ i &= 146\ 11\ 3\cdot78 \end{aligned}\right\} \text{M.E. } 1897$$

$\log q = 0\cdot0263786$

Middle place.

$c - 0$

$\cos\beta'\Delta\lambda' = 6''\cdot7. \qquad \Delta\beta' = 1'\cdot1.$

There is an error in the elements published in the *Astronomische Nachrichten* 3394, the longitude of the ascending node should read 86° 27′ 51″·1 instead of 86° 17′ 51″·1.

Sydney: 1897 *April* 10.

The Expected Shower of Leonids in 1897. By W. F. Denning.

The return of the *Leonids* in November next, though it may fairly be expected to afford a pretty abundant display, will occur in the presence of a gibbous Moon and thus lose much of the conspicuous character which it may quite possibly have exhibited in a dark sky. At midnight following November 14 the Moon will be twenty days old and therefore nearing her last quarter (November 17, $2^h\ 2^m$), but her light will be sufficiently strong to overpower many of the smaller meteors and to moderate the apparent brilliancy of the larger ones.

In November we shall be placed fully two years before a maximum return is expected, and the density of that part of the stream so far in front of its associated comet is not likely to be considerable, but we may get a shower of perhaps fifty or sixty *Leonids* per hour for one observer on the night following November 14. It must be remembered that the radiant does not rise on that date until 10^h15^m P.M. and passes the meridian at 6^h30^m on the following morning. Observations are not, therefore, likely to be very productive until after midnight in consequence of the unfavourable position of the radiant.

In 1831 (two years preceding the great American shower of 1833) a French naval officer, Captain Berard, commanding the brig, *Le Loiret*, reported to M. Arago that "on November 13, at four in the morning, the sky being perfectly cloudless and a copious dew falling, he saw a number of shooting stars and luminous meteors of great dimensions. During upwards of three hours more than two per minute were seen." Dr. Wright, of Ohio, U.S.A., also witnessed an abundant fall of meteors on the same morning. In 1864 (two years before the fine European display of 1866) a star-shower of considerable strength was observed from the s.s. *Ellora*, off Malta, on the morning of November 13, for according to the report of those on board "there was a brilliant display of meteors all through the watch."

Seeing, therefore, that marked showers presented themselves in 1831 and 1864, we appear justified in expecting a tolerably active display in 1897. By a comparison of the observations made of the *Leonids* in 1895 and 1896 (*Monthly Notices*, lvi. 255, and lvii. 277), it will be noticed that a marked increase occurred in the latter year. A relatively far greater increase may be expected in the coming November, though the richest part of the stream will probably envelope the earth during daylight in England on November 14 and pass unseen.

From a comparison of the "brilliant showers" which occurred in the years 1865, 1866, 1867, and 1868, Mr. B. V. Marsh, of Philadelphia, U.S.A., concluded that there probably existed three concentric meteor-groups. "The densest or middle part of the meteoric dream through which the earth passed in 1866 (observed in Europe) and 1867 (observed in America)

appears to be flanked on either side by lateral and somewhat less dense and wider meteoric currents, at a distance from the orbit of the main stream, which the earth crossed in about twelve hours on the mornings of 1865 November 13, and 1867 November 15." (*B.A. Report*, 1869, p. 302.)

Assuming the node to advance along the ecliptic at the average rate, shown by a comparison with the times of old observations, of fifty-seven minutes of arc, with reference to a mean moveable equinox, during one period of revolution, then the stream recurs six and a half hours later in an ordinary year, and seventeen and a half hours earlier in leap year. Thus it is only the half hour which progressively accumulates and with leap year dropped once in 3 centuries out of 4, as in 1700, 1800, and 1900, throws forward the date of the shower's recurrence by about 3 days in a century.*

The central meteoric group observed in 1866 and 1867 is not likely to be visible in England this year, as the earth will be involved with it at about noon on November 14, but the other two streams ought to furnish many meteors on the preceding and following mornings. If the motion of the node of the meteoric orbit has continued its previous rate since 1866 then the three groups, conjectured to exist by Mr. Marsh, ought to be centrally passed by the earth at the following times :—

Group		h.	Duration.		From obs. in
Preceding	Nov. 13	$9\frac{1}{4}$	12 hours	1865, Nov. 12,	America
Central	14	0	$4\frac{1}{3}$ „	1866–7, „ 13,	Europe and America
Following	14	15	$13\frac{1}{3}$ „	1867–8, „ 14,	China and America

The earth's longitude on November 14 at noon is 52° 25′.

With regard to this peculiarity of construction it must be confessed that it rests on somewhat slender evidence, especially in respect to the sparse intervals supposed to outlie the central group. The observations on which the theory depends were only those furnished by five showers at the last epochal return, and it is hoped that during the next seven years a large number of new data may be obtained, at places differing widely in longitude, to assist in the solution of this problem. Under more favourable circumstances the voids near the central current may be found less definite than supposed, but there can be no doubt of the shower's rich sustenance during a period of more than forty-two hours. In meteoric astronomy it is sometimes the unexpected which happens, so that, without placing implicit reliance on the exact times of occurrence of predicted phenomena, observers should watch carefully throughout those nights which offer the best general prospect of success.

In 1898 and 1901 there will be no moonlight to interfere with the brilliant aspect of the shower, in 1900 the Moon will be half illuminated, and in 1899 and 1902 our satellite will be near the full. In England we should probably have witnessed the most brilliant

* See an interesting letter and diagram, explanatory of this part of the subject, in *Nature*, 1896 December 24, by Professor A. S. Herschel.

display of all in 1899, as it is due at about 1 A.M. on November 15, but the flood of moonlight over the sky will operate most unfavourably upon the visible nature of the phenomenon. In 1900 the circumstances are more to our advantage, and an unusually fine exhibition seems likely to occur just before sunrise on November 15, but the sky will be rather light in the presence of a moon at her last quarter.

One of the features which ought to be ascertained at every return is the time of apparent maximum of the shower. In deducing this the height of the radiant ought perhaps to be considered, for a radiant near the zenith will apparently yield more meteors than a stronger system with its radiant at a low altitude. In fact, the visible strength of a radiant depends largely, as pointed out by Lieut.-Colonel Tupman some years ago, upon its zenithal distance. The hourly number of meteors, for a radiant at the zenith, may be computed by multiplying the number actually counted in an hour by the secant of the zenith distance of the radiant. The number so derived will give the number of meteors which would have diverged from the radiant had it occupied a place in the zenith.

Another circumstance affecting the hourly number of *Leonids*, but chiefly during a comparatively weak display, is that there are many other showers of streak-leaving meteors in and surrounding *Leo* at the middle of November. Some observers count all the meteors shooting from the general direction of *Leo* as *Leonids*, and thus the actual number of the latter is exaggerated. Allowance should always be made for these minor streams. A list of their radiants appears in *Popular Astronomy*, 1894 March, and *The Observatory*, 1897 January. The principal of them are situated near δ and ι *Cancri*, μ, and ξ *Ursæ Majoris*, and π, λ, τ and β *Leonis*.

The real paths of several interesting *Leonids* and *Cancrids* were determined, in 1896 November, as the result of simultaneous observations at various stations. If a few additional observers co-operated to gather similar materials during the ensuing return a large number of meteors might be secured, and not only *Leonids* but members of the numerous contemporary showers such as *Taurids*, *Perseids*, *Aurigids*, *Cancrids*, *Ursids*, &c., might have their heights, radiants, &c., accurately attributed. It is proposed to make a special effort in this direction and to arrange for systematic watching during several hours on the mornings of November 14, 15, and 16 next. If observers in the N. of England looked to South, while those in the S. of England looked to North, and those in the S.E. and S.W. districts directed their observation to the north-west and north-east respectively, and recorded the apparent flights of the most conspicuous meteors which appeared, a plentiful collection of doubly observed objects would sure to be discovered amongst the observations.

Bristol: 1897 *June* 7.

Ephemeris for Physical Observations of the Moon, 1897 September to 1898 April. By A. Marth.

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Sept. 4	4·80	−0·93	+2·45	+4·84	5·42	333·2
5	17·00	0·95	3·29	3·56	4·85	317·3
6	29·19	0·98	3·98	2·09	4·49	297·8
7	41·38	1·00	4·49	+0·51	4·52	276·5
8	53·56	1·02	4·82	−1·07	4·94	257·5
9	65·74	1·05	4·98	2·57	5·60	242·7
10	77·91	1·07	+4·95	3·91	6·30	231·6
11	90·08	1·09	4·71	5·02	6·88	223·1
12	102·25	1·11	4·26	5·86	7·24	215·9
13	114·42	−1·13	3·59	6·40	7·33	209·2
14	126·60	1·15	2·71	6·63	7·16	202·1
15	138·78	1·17	1·65	6 56	6·77	194·1
16	150·97	1·19	+0·45	−6·21	6·23	184·1
17	163·16	1·20	−0·85	5·59	5·66	171·4
18	175·35	1·22	2·16	4·73	5·20	155·5
19	187·55	1·23	3·42	3·66	5·01	137·0
20	199·75	1·25	4·53	2·42	5·13	118·1
21	211·96	1·26	5·41	−1·03	5·50	100·9
22	224·17	−1·27	−5·97	+0·43	5·98	85·9
Oct. 2	346·36	−1·39	+4·36	+3·63	5·67	309·9
3	358·55	1·41	5·12	2·20	5·57	293·3
4	10·74	1·42	5·60	+0·66	5·63	276·7
5	22·92	1·43	5·81	−0·89	5·88	261·3
6	35 09	1·44	5·81	2·36	6·26	247·9
7	47·26	1·46	+5·60	−3·68	6·74	236·6
8	59·42	1·47	5·23	4·79	7·09	227·4
9	71·58	1·48	4·70	5·65	7 34	219·6
10	83·74	1·49	4·01	6·22	7·40	212·6
11	95·90	−1·49	3·16	6·50	7·22	205·8
12	108·05	1·50	2·15	6·48	6·83	198·3
13	120·21	1·51	+1·01	−6·17	6·25	189·2
14	132·37	1·51	−0·26	5·59	5·59	177·4
15	144·54	1·52	1·60	4·77	5·03	161 5
16	156·71	1·52	2·96	3·75	4·78	141·8

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Sel. Long. of the Earth.	Geocentric Libration Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Oct. 17	168·88	1·52	4·27	2·57	4·91	121·0
18	181·06	1·52	5·44	−1·24	5·58	102·8
19	193·24	1·52	6·38	+0·17	6·38	88·5
20	205·43	−1·52	−6·99	+1·60	7·17	77·1
Nov. 1	351·85	−1·51	+6·90	−1·41	7·05	258·5
2	4·02	1·51	7·04	2 84	7·59	248·0
3	16·19	1·51	6·87	4·09	7·99	239·1
4	28·35	1·51	6·45	5·12	8·23	231·4
5	40·50	1·50	5·84	5·87	8·29	224·7
6	52·65	1·49	5·05	6·34	8·10	218·4
7	64·80	1·49	4·13	6·52	7·72	212·2
8	76·94	1·48	3·09	6·41	7·11	205·6
9	89·08	1·47	1·95	6 20	6·49	197·4
10	101·22	−1·46	+0·70	5·64	5·68	187·1
11	113·37	1·45	−0·61	4·83	5·87	172·8
12	125·51	1·44	1·98	3·82	4·30	152·7
13	137·66	1·43	3·34	2·64	4·26	128 3
14	149·81	1·42	4·68	−1·33	4·86	105·9
15	161·96	1·40	5·84	+0·05	5·84	89·5
16	174·12	1·39	6·82	1·45	6·97	77·9
17	186·29	1·37	7·49	2·82	8·00	69·3
18	198·46	1·36	7·80	4·09	8·80	62·2
19	201·64	−1·34	−7·61	+5·18	9·20	55·6
Nov. 29	332·56	−1·21	+7·42	−2·18	7·73	253·6
30	344·73	1·19	7·66	3·59	8·45	244·8
Dec. 1	356 89	1·18	7·52	4·76	8·89	237·5
2	9·05	1·16	7·06	5·67	9·05	231 1
3	21·20	1·14	6·34	6·29	8·92	225·0
4	33·35	−1·12	+5·41	−6·61	8·53	219·1
5	45·49	1·10	4·33	6·63	7·92	213·0
6	57·63	1·08	3·15	6·36	7·09	206·2
7	69·77	1·06	1·88	5·81	6·11	197·9
8	81·90	1·04	+0·57	−5·02	5·05	186·5
9	94·03	−1·01	−0·77	4·00	4·08	169·2
10	106·16	0·99	2·10	2 81	3·51	143·3
11	118·29	0·96	3·39	1·49	3·71	113·8
12	130·43	0·94	4·61	−0·10	4·61	91·2

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1897.	°	°	°	°	°	°
Dec. 13	142·57	−0·91	−5·69	+1·32	5·85	76·9
14	154·71	0·89	6·59	2·71	7·12	67.6
15	166 86	0·86	7·22	3·99	8·25	61·0
16	179·01	0·83	7·53	5·10	9·09	55·8
17	191·17	−0·81	−7·45	+5·98	9·54	51·1
Dec. 28	325·19	−0·56	+7·34	−4·68	8·70	237·3
29	337·36	0·53	7·36	5·61	9·24	232·5
30	349·52	0·51	6·99	6·31	9·41	227·7
31	1·68	0·48	6·30	6·70	9·19	223·0
1898.						
Jan. 1	13·83	−0·45	+5·36	−6·78	8·63	218·1
2	25·98	0·43	4·22	6·56	7·80	212·6
3	38·12	0·40	2·96	6·05	6·74	206·0
4	50·26	0·37	1·63	5·29	5·54	197·1
5	62·39	0·34	+0·29	4·30	4·33	186·0
6	74·52	0·31	−1·03	3·13	3·29	161·7
7*	86·65	0·27	2·29	1·80	2·91	128·3
8	98·78	−0·24	3·44	−0·39	3·46	96·4
9	110·91	0·21	4·45	+1·06	4·58	76·6
10	123·04	0·18	5·28	2·48	5·83	64·8
11	135·18	0·15	5·95	3·80	7·06	57·3
12	147·32	0·12	6·36	4·96	8·06	51·9
13	159·46	0·08	−6·51	5·89	8·77	47 7
14	171·61	0·05	6·36	6·52	9·10	44·1
15	183·77	−0·03	5·90	+6·81	9·00	40·7
16	195·93	0·00	5·13	6·70	8 43	37 2
17	208·10	+0·03	4·05	6·19	7·39	33·0
18	220·28	0·06	2·71	5·28	5·94	27 0
19	232·46	0·08	−1·17	4·02	4·18	16·2
20	244·65	0·10	+0·46	2·47	2·51	349 5
21†	256·84	0·13	2·08	+0·76	2·21	290 0
22	269·03	0·15	3·56	−0·99	3·70	254·4

* During the small partial eclipse of the Moon on 1898 January 7. which, according to the *Nautical Almanac* for 1899, p. xiii. begins at $11^h\ 47^m{\cdot}4$ and ends at $13^h\ 22^m{\cdot}4$, the shadow does not seem to pass over any spot of well determined selenographical position.

† During the eclipse of January 21 the selenographical longitude Λ and latitude B of the point on the lunar surface in the centre of the shadow-cone

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Jan. 23	281·23	0·18	4·81	2·65	5·49	241·1
24	293·42	0·20	5·74	4·10	7·05	234·3
25	305·61	0·23	6·29	5·28	8·20	229·9
26	317·79	+0·25	+ 6·44	−6·12	8·88	226·3
27	329·97	0·28	6·20	6·63	9·07	222·9
28	342·14	0·31	5·61	6·80	8·81	219·3
29	354·31	0·33	4·71	6·61	8·15	215·1
30	6·47	0·36	3·59	6·22	7·18	209·9
31	18·62	0·39	2·32	5·52	5·99	202·7
Feb. 1	30·77	+0·42	+0·97	−4·59	4·69	191·9
2	42·92	0·45	−0·39	3·46	3·49	173·6
3	55·06	0·48	1·67	2·18	2·75	142·5
4	67·20	0·51	2·83	−0·78	2·94	105·5
5	79·34	0·54	3·82	+0·67	3·87	80·1
6	91·47	0·57	4·58	2·11	5·04	65·3
7	103·60	+0·60	5·11	3·47	6·18	55·7
8	115·74	0·63	−5·38	4·68	7·13	48·9
9	127·88	0·66	5·41	5·67	7·83	43·5
10	140·02	0·69	5·20	6·36	8·21	39·1
11	152·17	0·72	4·78	6·72	8·23	35·3

and the position angle P of the Moon's axis, reckoned as usually from the declination circle, will be

	h			
1898 Jan. 21	16	Gr. Λ = + 5°·03	B = −0°·12	P = 348·45
	18	4·02	0·12	·48
	20	3·00	0·13	·50
	22	+2·98	−0·13	348·53

The selenographical longitude λ and latitude β of the point on the rim of the Moon's disc in position angle p are found by

$$\sec s' \cos\beta \sin(\Lambda-\lambda) = \sin(p-P)$$
$$\sec s' \cos\beta \cos(\Lambda-\lambda) = -\cos(p-P)\sin B + \tan s' \cos B$$
$$\sec s' \sin\beta = \cos(p-P)\cos B + \tan s' \sin B,$$

where s' is the apparent semidiameter of the Moon's disc, or, if it is not worth while taking s' and B into account, if

$p-P$ is between 0° and 180°, by $\lambda = \Lambda - 90°$ and $\beta = 90° - (p-P)$

and if

$p-P$ is between 180° and 0°, by $\lambda = \Lambda + 90°$ and $\beta = 90° + p - P$.

The position-angle of the axis of the Sun will be 351°·78 and the heliographical latitude of the centre of the disc - 5°·39.

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Geocentric Libration. Sel. Long. of the Earth.	Lat.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Feb. 12	164·32	0·74	4·16	6·69	7·87	31·8
13	176·48	0·76	3·38	6·28	7·12	28·2
14	188·65	+0·78	−2·46	+5·48	6·00	24·1
Feb. 24	310·59	+0·98	+5·06	−6·67	8·36	217·0
25	322·78	1·01	4·51	6·62	8·00	214·1
26	334·97	1·03	3·65	6·26	7·24	210·1
27	347·15	1·05	2·55	5·63	6·18	204·3
28	359·33	+1·07	+1·28	−4·76	4·93	195·0
Mar. 1	11·50	1·09	−0·08	3·70	3·70	178·7
2	23·66	1·11	1·44	2·47	2·86	149·8
3	35·82	1·14	2·72	−1·13	2·94	112·5
4	47·98	+1·16	−3·81	+0·28	3·82	85·7
5	60·13	1·18	4·66	1·71	4·96	69·9
6	72·28	1·20	5·21	3·08	6·05	59·4
7	84·43	1·22	5·44	4·32	6·94	51·4
8	96·57	1·24	5·33	5·36	7·55	44·7
9	108·72	+1·26	−4·91	+6·12	7·84	32·6
10	120·87	1·27	4·24	6·54	7·79	32·8
11	133·02	1·29	3·37	6·58	7·39	27·0
12	145·18	1·30	2·40	6·22	6·67	21·1
13	157·34	1·32	1·40	5·48	5·65	14·3
14	169·51	+1·33	−0·40	+4·40	4·42	5·2
Mar. 24	291·55	+1·42	+4·11	−6·53	7·71	212·1
25	303·76	1·43	3·47	6·23	7·13	209·0
26	315·97	1·44	2·57	5·66	6·21	204·3
27	328·18	1·45	1·44	4·83	5·04	196·5
28	340·38	1·46	+0·15	3·81	3·81	182·2
29	352·57	+1·47	−1·23	2·63	2·90	154·9
30	4·76	1·48	2·61	−1·33	2·93	117·1
31	16·95	1·49	3·89	+0·04	3·88	89·5
Apr. 1	29·13	1·50	4·97	1·42	5·17	74·0
2	41·30	1·50	5·77	2·77	6·40	64·3
3	53·47	+1·51	−6·22	+4·02	7·40	57·1
4	65·64	1·52	6·25	5·09	8·06	50·7
5	77·80	1·52	5·87	5·91	8·32	44·7
6	89·96	1·53	5·09	6·41	8·17	38·3
7	102·12	1·53	3·99	6·52	7·64	31·3

Greenwich Noon.	Selenographical Colong. of the Sun.	Lat.	Sel. Long. of the Earth.	Geocentric Libration. Lat.	Combined Amount.	Direction.
1898.	°	°	°	°	°	°
Apr. 8	114·28	+1·53	2·67	+6·22	6·77	23·1
9	126·45	1·53	−1·26	5·52	5·66	12·8
10	138·62	1·53	+0·12	4·46	4·47	358·4
11	150·80	1·53	1·39	3·12	3·42	336·1
12	162·98	1·53	2·47	+1·60	2·94	302·9
13	175·17	1·52	3·35	−0·00	3·35	269·9
14	187·37	1·52	4·03	1·58	4·33	248·5
15	199·58	+1·51	+4·51	−3·05	5·44	235·9

The selenographical positions of the Sun at the times assigned to the five published plates of the Lick Observatory Atlas of the Moon are the following ;—

Selenographical Colong. of the Sun.	Lat.	Assigned Pacific Standard Times.			
°	°		h m s	s	
184·77	−0·93	1895 Oct. 10	16 49	10–17	Plate 1
172·64	−0·91	1895 Oct. 9	16 55	30–40	„ 2
159·56	−0·89	1895 Oct. 8	15 9	10–20	„ 3
172·62	−0·91	1895 Oct. 9	16 53	2–12	„ 4
61·07	−1·40	1896 Oct. 18	10 32	41–47	„ 5

The data for ascertaining the times when, for a number of spots represented on the photographs, the Sun reaches the zenith distances corresponding to those at the assigned times, are given in the following list, the data for plate 1 being already included in the list on page 90, under "Lick 6."

Sun's Colongitude. ⊙'s.		Spot.	Pl.	Sun's Colongitude. ⊙'s.		Spot.	Pl.
58°·68	−1·696 lat.	Horrebow	5	158°·48	−1·214 „	Cuvier	3
59·06	−1·421 „	Bouguer	5	158·58	−1·111 „	Tycho	3
59·34	−1·220 „	Bianchini	5	158·59	−1·093 „	Clairaut	3
59·47	−1·136 „	Sharp	5	158·71	−0·954 „	Maurolycus	3
59·70	−0·969 „	C. Heraclides	5	158·93	−0·706 „	Gemma Frisius	3
59·73	−0·953 „	Harpalus	5	159·02	−0·609 „	Aliacensis	3
59·87	−0·849 „	Mairan	5	159·10	−0·522 „	Apianus	3
60·16	−0·639 „	Delisle	5	159·17	−0·441 „	Sacrobosco	3
60·22	−0·600 „	Wollaston	5	159·26	−0·342 „	Geber	3
60·36	−0·498 „	Euler	5	159·34	−0·244 „	Abulfeda	3
60·38	−0·480 „	Pytheas	5	159·38	−0·210 „	Albategnius	3
60·45	−0·442 „	Aristarchus	5	159·68	−0·990 „	Stöfler	3

Sun's Colongitude. ⊙'s lat.		Spot.	Pl.
167°·73	−5·50	Newton	2
170·08	−2·837	Moretus	2
170·58	−2·287	Blancanus	2
170·72	−2·135	Scheiner	2
171·11	−1·698	Clavius	2
171·11	−0·586	Aliacensis	2
171·23	−1·570	Longomontanus	2
171·37	−1·394	Lilius	2
171·52	−1·235	Maginus	2
171·75	−0·989	Tycho	2
171·77	−0·957	Stöfler	2
171·96	−0·754	Cichus	2
172°·05	−0·650	Hell	2
172·09	−0·608	Pitatus	2
172·17	−0·494	Purbach	4
172·26	−0·401	Thebit	4
172·36	−0·292	Alpetragius	4
172·41	−0·235	Alphonsus	4
172·44	−0·201	Albategnius	4
172·48	−0·158	Ptolemaeus	4
172·49	−0·143	Hipparchus	4
172·57	−0·057	Mösting A.	4
172·69	+0·072	Triesnecker A.	4
172·73	+0·118	Bode	4

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Personality in Measurements of Photographs for the Astrographic Catalogue, at the University Observatory, Oxford. By H. H. Turner, M.A., F.R.S., Savilian Professor.

1. In the measurement of the plates for the Astrographic Catalogue at this observatory special care has been taken to eliminate systematic error of bisection. Every plate is measured twice in reversed positions (turned in its own plane through 180°), and the two measures of each star are compared. We thus obtain :—

(*a*) A check on mistakes of comparatively large amount.

(*b*) Information as to error of bisection, which affects the two measures of any star in opposite directions, and thus appears doubled in the difference.

(*c*) The elimination of the error of bisection by taking the mean of the two measures.

(*d*) Information as to the probable error of a single measure.

The main object of the present note is to show how little photographic measures are affected by error of bisection. The micrometer used here is described in *Monthly Notices*, vol. lv. p. 102, and has a scale in the focus of the eyepiece divided to $3''{\cdot}0$ and reading by estimation to $0''{\cdot}3$. It does not profess the greatest possible accuracy, but in the present paper it is shown

that the systematic errors are very small indeed ; and experience has proved that the accidental errors are much smaller than might be expected.

2. The main points of the paper may be summarised as follows, under the several paragraphs :—

§ 4. The general personality or error of bisection for a given measurer and instrument rarely exceeds 0″·15, or half the estimated unit. Its mean value, irrespective of sign, is 0″·09.

§ 5. The measurer and his instrument must be taken together. A change in either means a new personality.

§ 6. The personality remains sensibly constant for some months at least.

§ 7. The probable error of a determination of personality from a single plate (of about 200 stars) is less than ±0″·05.

§ 8. The variation of personality with stellar magnitude is very small ; and what there is can be detected and eliminated by reversing the plate. Hence we may look to photographic measures with confidence as a means of ridding star-places of systematic error depending on magnitude of the star.

§ 10. The probable error of a single measure is about ±0″·24, and of the mean of two, ±0″·17 ; thus the results satisfy the conditions imposed by the Comité Permanent last May.

3. *Method of Reversal.*—It may be well to explain here the exact method adopted in reversing the plate. At the Royal Observatory, Greenwich, I believe both the plate and the measuring scale are rotated through 180°, so that, though the directions of measurement (both right and left and up and down) are reversed to the observer's eye, the figures recording the star's position in both coordinates are approximately the same as before. The figures printed on the eye-piece scale are read upside down, but this is a mere detail ; the estimated fraction of a division is now to the right instead of the left, or up instead of down, the same actual division being in use. At Oxford, on the other hand, the scale is not reversed, only the plate, so that if the measured coordinates of a star were in the direct position (denoted D), say 3·057 and 17·304, then in the reversed position (denoted R) they are approximately 22·943 and 8·696—*i.e.*, the differences of the former from 26·000, which is the length of a side of the measuring reseau. Suppose 22·941 and 8·697 are actually recorded in the R position. Then before comparison with the D measures, the R measures are subtracted from 26·000, giving 3·059 and 17·303 respectively. The differences of these from the D measures are then tabulated as +·002 and −·001 respectively, the errors of bisection being half these amounts. The method adopted at Greenwich obviates this subtraction ; but it is considered that the greater independence of the readings at Oxford is worth the extra trouble. Since two entirely different divisions of the eye-piece scale are employed at Oxford, there will also be a slight decrease of apparent accuracy, owing to the errors of scale

divisions ; but, as in other similar cases, this increase of accidental error is accompanied by a decrease of systematic error.

4. *General Personality for Different Measurers.*—To give an idea in the first instance of the kind of quantity under discussion, the following table shows the mean error of bisection (*i.e.*, *half* the mean difference R − D) for all stars on a considerable number of plates for different observers and different instruments. For the way in which the probable errors of these quantities shown in column six have been calculated see § 7. They depend, of course, on the number of plates, shown in column five.

TABLE I.

Mean Error of Bisection in Photographic Measures.

Measurer.	Inst.	Error of Bisection. Coord. x.	Coord. y.	No. of Plates.	Prob. Error of Mean.
		″	″		″
B.	α	+0·12	+0·24	17	±0·01
B.	β	+0·20	−0·03	7	±0·02
F.	β	−0·06	+0·13	36	±0·01
H.	α	−0·02	+0·02	12	±0·02
H.	β	−0·13	+0·07	10	±0·02
C.	α	−0·18	0·00	16	±0·02
C.	β	−0·12	+0·04	4	±0·03
M. H.	α	−0·09	+0·27	6	±0·02
M.	μ	−0·03	+0·06	16	±0·02

Considering that the single star places are only read off by estimation to 0″·3, these quantities are very small, although well defined, as the probable errors of the last column show. But only in four cases out of eighteen do they exceed 0″·15 (the half of a unit in the last place), and even for a plate measured by several different measurers it seems unprofitable to apply them. Only a few plates have been measured at Oxford by different measurers ; for the great majority the same measurer has measured it throughout, and thus the personality is completely eliminated. The few exceptions, measured by miscellaneous measurers at the beginning of the work, have all been re-measured by a single measurer, and thus the mean of the two sets is only affected with half such personalities as shown above.

5. *Change of Instrument.*—If the measurer changes to another instrument he must be treated as a new measurer. This is exemplified especially in the case of B. in the above table, who changed from +0″·12 to +0″·20 in x, and from +0″·24 to −0″·03 in y, when he changed from one measuring machine to another (of the same pattern). To test the reality of the change

he measured first with α, then with β, and then with α again; and it was found that he returned at once to his old personality with α. On the other hand, changing from α to β did not produce nearly such an effect on H. and C. There is nothing gained by analysing the effects of the measurer and instrument separately. They must be taken together, and if either is changed we must expect a new result.

6. *Progressive Change with Time.*—The question whether these personalities are fairly constant may be answered in the affirmative. The Oxford measurers were all new to the work, and from the analogy of transit personal-equations we should expect any change to be most marked at the beginning of the work. But at present no sensible changes have appeared. Take, for instance, F., who has a long series of plates with the same machine. Dividing his measures into groups in order of date we find

No. of Plates.	Mean Dates of Measures. D	R	x	y
			"	"
10	1896 Sept. 9	1896 Nov. 16	−·07	+·10
10	1896 Oct. 15	1896 Nov. 3	−·13	+·20
10	1897 Jan. 21	1897 Jan. 29	+·01	+·13
6	1897 Apr. 5	1897 Apr. 24	−·07	+·10

The accordance between the first and last of the series being curiously complete. It is needless to multiply instances, as the work has as yet only been going on for some months, and changes may make their appearance in the future. Meantime it seems probable that they will develop gradually, if at all.

7. *Probable Error of a Determination.*—We can thus treat a series of plates measured by the same measurer with the same instrument as homogeneous, and available without further modification for determination of probable error. Different series give *mean* errors for a single plate varying between $\pm 0''{\cdot}04$ and $\pm 0''{\cdot}07$. Thus, without making an elaborate computation, we may assume the *probable* error of a determination from a single plate to be at least as small as $\pm 0''{\cdot}06$. Dividing by the square root of the number of plates we get the results shown in the sixth column of Table I.

For illustration, the best and the worst of the different series at present available are given below. Each result refers to a whole plate, and thus depends on the measurement of (roughly speaking) 200 stars. No attempt has been made to assign different weights to the plates according to the number of stars.

Series I.

Measurer M. Inst. μ. Coordinate y.

Plate.	Error of Bisection.	Diff. from Mean.
	″	″
653	+·07	+·01
883	+·11	+·05
380	+·09	+·03
375	+·03	−·03
376	+·03	−·03
374	+·03	−·03
368	+·02	−·04
362	+·01	−·05
377	+·16	+·10
383	+·14	+·08
384	·00	−·06
784	+·10	+·04
785	+·03	−·03
250	+·08	+·02
268	+·06	·00
269	+·03	−·03
Mean	+·06	±·04

Series II.

Measurer H. Inst. β. Coordinate y.

Plate.	Error of Bisection.	Diff. from Mean.
	″	″
749	·00	−·08
750	+·05	−·03
889	−·09	−·17
412	+·10	+·02
414	·00	−·08
787	+·08	·00
788	+·14	+·06
791	+·12	+·04
300	+·30	+·22
628	+·09	+·01
Mean	+·08	±·07

The Series I. was made by a measurer* who had had considerable practice in micrometric measurement at the telescope. Series II. are the first measures of an entirely inexperienced measurer; is much shorter, and shows some evidence of progressive change, by allowing for which we could reduce the $\pm''\cdot07$ to $\pm''\cdot06$ at least. Other series fall between these extremes, and the probable error for a single plate is most likely less than $\pm''\cdot05$. The estimates in column six of Table I. are thus fairly liberal.

8. *Variation with Stellar Magnitude.*—We now come to a more important question. Is this error of bisection the same for all stars? In the case of transit-personal-equations attention has of late years been called to the fact that they vary with the brightness of the star observed. The photographic method seems to offer a means of checking such errors in meridian observations, and it has been shown by Mr. Hinks (*Monthly Notices*, vol. lvii. p. 473) how it can be used to good purpose in this way. But are measures on photographs entirely free from errors of this kind? The expedient of reversing the photograph enables us to eliminate them, even if existent; but it is more comfortable to be assured of their non-existence if possible, or at least of their smallness.

* Mr. T. J. Moore, of the Leeds Astronomical Society. It is to be remarked to his credit that micrometer μ is only a wooden model, which he thus used to very good purpose. He now has a properly made metal micrometer.

To investigate this point the measures on a number of plates have been divided into groups according to the size of disc of the star measured. The size of disc is a rough (see § 9) indication of the magnitude, nevertheless good enough for our purpose; and the results are exhibited in tabular form below.

TABLE II.

Variation of Bisection-error with Stellar Magnitude.

Measurer.	Coordinate.	Error of Bisection in Group I.	II.	III.	IV.	V.	No. of Stars in Group I.	II.	III.	IV.	V.
		″	″	″	″	″					
F.	x	−·02	−·08	−·08	+·08	+·06	453	537	216	171	18
H.	x	+·02	−·08	−·21	−·27	−·20	833	410	165	138	8
C.	x	−·18	−·23	−·17	−·08	−·29	397	402	149	146	20
M.	x	−·02	−·02	+·05	−·06	−·05	258	338	140	143	15
F.	y	+·24	+·15	·00	+·21	+·27	454	548	219	171	18
H.	y	+·05	+·11	+·08	+·08	−·17	849	395	172	153	8
C.	y	−·03	−·02	+·05	+·06	+·12	406	407	148	150	15
M.	y	+·06	+·08	+·02	+·09	+·03	245	334	137	144	13

The groups are arranged as follows :—

Group	I.	Estimated diameter of disc .	″0·3 to ″3·0
,,	II.	,, ,, ,, .	3·3 ,, 4·5
,,	III.	,, ,, ,, .	4·8 ,, 6·0
,,	IV.	,, ,, ,, .	6·3 ,, 12·0
,,	V.	,, ,, ,, .	over 12·0

Group I. thus comprises all the faint stars, of about magnitude 11, and Group V. the bright stars of magnitude 8 and brighter.

I think it will be clear from the above table that there is nothing to be anxious about in such measures. Some measurers show an almost complete independence of stellar magnitude, as for instance M., and the largest range shown is ″0·29 (H. IV. −H. I.). It is to be remembered that even these small differences, if real, can easily be detected and also eliminated by reversal of the plate; and the hope that the photographic method offers us an escape from this troublesome error seems well grounded.

9. *The Determination of Magnitudes.*—The size of disc has been described in the preceding paragraph as a *rough* estimation of magnitude. This point cannot here be fully examined, but one or two remarks may be made. Firstly, the diameters of the discs are estimated very differently by different measurers. If all measurers estimated them alike, we should expect to find the numbers of stars in the different groups proportional to one another. But, on looking at the above Table II., it is seen that H. makes

Group I. contain twice as many as Group II.; while others make Group II. the larger. Secondly, it is especially the fainter stars which are differently estimated. Those who have tried such estimations will recognise that for the faint stars the intensity of the patch as well as its size should be taken into account, but it is difficult to do so.

It is not without precedent that the accurate photometry of the stars should lag behind the determination of their positions; for this has been the case all along. Positions are not only easier to determine, but more pressingly needed. As an illustration, I may refer to a paper (in No. 411 of the *Astronomical Journal*, received as I am writing), by Professor Howe on Comet 1896, VI., wherein he requires the places of 173 comparison stars. The collection of these from various sources has doubtless involved much labour, which will be considerably reduced when such measures of position as those above considered are complete. But Professor Howe does not *want* the magnitudes of the stars; he does not even mention them in the paper.

10. *Probable Error of the Measures.*—When a plate has been measured in the two positions, and the differences of the measures formed, each difference is one of the numbers -5, -4, -3, -2, -1, 0 $+1$, $+2$, $+3$, $+4$, $+5$; the unit being $0^{r}\cdot001$ or $0''\cdot3$. Cases where the difference exceeds 5 ($=1''\cdot5$) are considered as due to some mistake, and *both* measures are repeated. If there is a clear mistake of say $^{r}\cdot010$ in one of the measures, it is altered or rejected: otherwise the mean of the four measures is taken. For the normal differences between -5 and $+5$ ($-1''\cdot5$ and $+1''\cdot5$) the number in each group is counted, giving results as follows (for an imaginary plate):—

Plate 2386, *Measurer X.*

	-5	-4	-3	-2	-1	0	$+1$	$+2$	$+3$	$+4$	$+5$
x	1	4	17	48	35	12	4	4	2	0	0
y	0	0	4	1	10	28	37	19	12	3	1

These numbers give us both the personalities above considered, and also the probable error of a measure. Thus the mean difference in the x coordinate is:

$$(-5\times1-4\times4-3\times17-\&c.)/127=-185/127=-\cdot0015.$$

and in the y coordinate:

$$(-3\times4-2\times1-1\times10+1\times37+\&c.)/115=+104/115=+\cdot0009,$$

giving personalities of half this amount, or $-0''\cdot22$ in x and $+0''\cdot14$ in y.

To find the probable error, we should subtract this mean from each difference and sum the residuals without regard to sign or their squares. But an approximate result may be obtained with less labour by considering the mean coincident with the residual which occurs most frequently, which in the above hypothetical

case would be -2 for x and $+1$ for y. (The actual mean for y is very near $+1$; but for x it lies midway between -1 and -2, and the assumption is thus of maximum inaccuracy.) We thus consider 0 written over the 48, ± 1 over the 17 and 35, ± 2 over the 4 and 12, and so on. And the mean error in x is:

$$\pm\{(17+35)\times 1+(4+12)\times 2+(1+4)\times 3+4\times 2+2\times 3\}/127 = \pm 113/127$$
$$= \pm^{r}\cdot 0009 \text{ or } \pm 0''\cdot 27,$$

and the probable error of a single measure is taken as:

$$\pm 0''\cdot 27\times\frac{1}{\sqrt{2}}\times\cdot 85 = \pm 0''\cdot 15.$$

Similarly in y the mean error is:

$$\pm\{(28+19)\times 1+(10+12)\times 2+(1+3)\times 3+(4+1)\times 4\}/115 = 123/115$$
$$= \pm\cdot 0011 \text{ or } \pm 0''\cdot 33,$$

and the probable error of a single measure is taken as $\pm 0''\cdot 19$.

Calculated in this way we obtain the following probable errors for the different measurers:—

Measurer.	Inst.	Mean Date.	x	y	No. Stars.
B.	α	1896 May 16	$\pm 0''\cdot 16$	$\pm 0''\cdot 20$	730
B.	α	1896 Oct. 27	$\pm 0\cdot 22$	$\pm 0\cdot 22$	960
B.	β	1897 Jan. 10	$\pm 0\cdot 20$	$\pm 0\cdot 16$	1076
F.	β	1896 Oct. 12	$\pm 0\cdot 27$	$\pm 0\cdot 27$	700
F.	β	1897 Apr. 10	$\pm 0\cdot 20$	$\pm 0\cdot 24$	430
H.	α	1896 Nov. 19	$\pm 0\cdot 27$	$\pm 0\cdot 29$	820
H.	α	1897 Feb. 20	$\pm 0\cdot 25$	$\pm 0\cdot 19$	900
H.	β	1896 Oct. 7	$\pm 0\cdot 27$	$\pm 0\cdot 26$	830
C.	α	1896 Nov. 10	$\pm 0\cdot 29$	$\pm 0\cdot 31$	370
C.	α	1897 Jan. 20	$\pm 0\cdot 27$	$\pm 0\cdot 20$	1010
C.	β	1897 Apr. 11	$\pm 0\cdot 27$	$\pm 0\cdot 24$	660
C.	β	1897 July 8	$\pm 0\cdot 26$	$\pm 0\cdot 25$	1940
M. H.	α	1897 July 11	$\pm 0\cdot 26$	$\pm 0\cdot 29$	680
M.	μ	1896 Nov. 4	$\pm 0\cdot 20$	$\pm 0\cdot 20$	430
M.	μ	1897 May 31	$\pm 0\cdot 17$	$\pm 0\cdot 20$	2000
		General Mean ...	$\pm 0\cdot 24$	$\pm 0\cdot 24$	

The mean of two measures thus has a probable error $\pm 0''\cdot 24\times\cdot 71 = 0''\cdot 17$, which satisfies the conditions settled by the Comité Permanent in 1896 May.

11. Each number is derived from five plates. The groups have been selected so as to show any improvement with practice which there may be; and such improvement is in several cases manifest. In this connection it may be interesting to give

the numbers of "discordances" found among the measures of each observer per 1,000 stars, and the number of stars missed on one occasion and noted on the other. The following numbers are obtained from ten plates each; containing about 2,000 stars generally.

Measurer.	Date.	Discordances per 1000.	No. Missed in D.	No. Missed in R.
B.	Early	50	50	94
B.	Recent	54	47	79
F.	Early	100	69	65
F.	Recent	75	55	75
H.	Early	131	66	60
H.	Recent	64	38	39
C.	Early	79	46	48
C.	Recent	43	44	44
M.	Early	82	71	68
M.	Recent	98	110	77
	General Mean ...	77·6	59·6	64·9

Occultation of Ceres by the Moon on 1897 November 13, visible at Greenwich.

(*Communicated by the Superintendent of the Nautical Almanac.*)

The following particulars of an occultation of *Ceres*, as visible at Greenwich, are communicated to the Society in the hope that under favourable conditions of weather it may be possible to observe the emersion of the planet; the Moon being 19 days old and the stellar magnitude of *Ceres* being 7·5.

	G.M.T. d h m	Angle from North	Angle from Vertex.
Immersion	13 10 37	56°	99°
Emersion	13 11 30	312	355

Nautical Almanac Office,
1897 *Sept.* 14.

Catalogue No. 2, of Nebulæ discovered at the Lowe Observatory, Echo Mountain, California. By Lewis Swift.

The following list of 25 new nebulæ, follows No. 1 (of 50), discovered at this Observatory and published in *Astronomical Journal* of 1896 November 13, and also in the *Publications of the Astronomical Society of the Pacific.* Since my return to this Observatory in April last, I have devoted my time to searching for comets as well as nebulæ, for which this anomalous climate is so well adapted. The following facts will illustrate its truth. The number of clear nights in 1897 May, were 25. Rainfall 0·87 of an inch. In June, 28, rainfall 0·10. Thus far in July, 26,

precipitation 0·15. I have never seen a month when every night was clear, but in 1896 June, every one was clear with a single exception, and that was foggy. One peculiarity of the climate is that there are more clear nights than days, which is the reverse of the conditions at the Warner Observatory, Rochester, New York.

No.	Date. 1895.	R. A. 1900·0 h m s	Dec. ° ′ ″	Description.
1	Mar. 23	8 5 38	+ 5 22 45	eeeF, vS, 1E, v close f 12^m *, D * nf points nearly to it.
2	1897. May 4	11 47 23	− 3 10 12	eF, pS, R, B * f 55^s, np of 2.
3	1895. Mar. 23	11 48 33	− 3 25 15	vF, pS, R, 2 B * in field, 1 n the other np.
4	23	11 48 48	− 4 34 15	eeeF, vS, 1E, a ray, in vacancy, 4 Fst in line S, 1 B and 3 Fstn.
5	1897. May 23	11 49 23	− 2 10 0	vF, vS, R, vFst near nf.
6	23	12 43 2	+54 59 45	eeF, S, cE, in field with N.G.C. 4732.
7	23	13 4 27	+53 22 48	vF, pL, R.
8	22	13 18 23	+ 6 45 16	eeeF, pS, cE, in vacancy, v dif.
9	June 25	13 47 20	+14 46 55	eeeF, pL, R, eee dif, 3^d of 4.
10	Apl. 20	13 47 38	− 0 38 0	vL, pF, cE in meridian, in field with 5334, F * close to each end of major axis. See note.
11	June 2	14 46 16	+27 59 17	eeF, S, 1E, pB * p, ee dif, another near suspected.
12	2	14 49 37	+16 47 5	vF, pS, R, only 1 st near, 10^m nf.
13	21	15 14 59	+ 2 8 52	vF, vE, pS, B * in field n partly obscures it.
14	3	15 19 52	+13 50 10	eF, pS, vF * close np.
15	21	15 30 0	+ 5 2 0	eF, pS, R, near the first of 6 or 8 st in a curved line.
16	July 22	16 18 45	+12 59 16	eeeF, S, 1E, F * near f, 2 Bst in field s nearly point to it, eee dif.
17	6	19 22 0	−36 24 5	B, eS, vE, stellar, looks like close D * both nebulous. Note.
18	6	19 49 10	−37 37 13	eeeF, pS, 3 st S, like belt of *Orion* point to it, eee dif.
19	6	19 53 17	−38 53 33	eeeF, S, 1E, precedes the below 37^s, ee dif, p of 2.
20	6	19 53 55	−38 53 33	eeF, pS, R, 8^m * f 20^s, p of 2.
21	8	19 59 0	−48 42 25	eeeF, pS, R, F * near n, ee dif, p of 2.
22	22	20 2 16	−45 55 45	vF, pS, R.
23	June 9	20 38 39	−30 16 30	eF, pS, vE, eeF * and a vF * near sf, point to it sp of 2.
24	9	20 38 45	−30 6 30	eeF, pS, vE, 8^m * 31′n, v dif, nf of 2.
25	July 7	22 35 0	−38 33 48	vF pS, R.

Notes.

No. 10. This is a remarkable object. I have never seen one just like it. It resembles an elliptical planetary nebula. The light is evenly diffused, and the limb as sharp as a planet. Strange Sir William Herschel missed it, being so near his III. 665. Munich 9619 is 121ˢ nf.

No. 17. This also is a singular object. I have never seen but one resembling it, and that was on the same night, which I think is N.G.C. 6861. It looks like a close, bright double star, each component having a small, bright, round, star-like nebulous disc. A power of 200 failed to divide it.

The places are for 1900·0, and the year of discovery, except when otherwise noted, is 1897.

N.G.C. 6550, must be struck out, as it is identical with H, III, 555.

Lowe Observatory, Echo Mountain, California, 1897 *July* 26.

Catalogue No. 3 of Nebulæ Discovered at the Lowe Observatory, Echo Mountain, California. By Lewis Swift.

List No. 1 of 50 nebulæ discovered here was published in *Astronomical Journal* of 1896 November 13. List No 2 (of 25 nebulæ) precedes the present list, and is also published in *Publications of the Astronomical Society of the Pacific.* This, as will be seen, consists of southern nebulæ exclusively. It is a field rich in nebulæ which that mighty 'Nimrod,' Sir William Herschel, who hunted the sky over, could not reach. Several are quite bright, and a few are interesting. I have examined Gale's ring nebula, R.A. $21^h\ 53^m\ 10^s$—39° 53′ 42″ and find it an interesting one, increasing the number now known to seven. It bears considerable resemblance to the one between β and γ *Lyræ*, but is not so bright, nor will it bear magnifying like that celebrated one, though it is too far south for me to do justice to it.

Nos. 1 and 6 are singular specimens, perhaps deserving of a new classification. I have seen three lately, all appearing alike. The third will appear in list four. N. G. C. 1288 is considerably elongated in 0°. It is not round as Sir John Herschel says. Our places agree. N. G. C. 1340 must be struck out. It is identical with 1344, as has been suspected. I examined thoroughly the locality for 1340, and I am certain that it does not exist. Some time I hope to take up this matter of doubtful nebulæ.

I am glad I have at length found in Barnard's field a nebula his keen eye failed to see. See No. 24.

No.	Date 1897.		R.A. 1900·0. h m s	Dec. ° ′ ″	Description
1	Aug.	10	0 46 45	−35 0 43	fB eeS, lE ; with 132 and 200 looks like a nebulous D *Uranus*.
2	Sept.	4	0 55 0	−40 53 51	vF, vS, R.
3		4	1 9 45	−33 11 33	eeF, S, eeE, a ray, no star nr.
4		4	1 23 35	−36 17 3	eeF, pS, R. vdif.
5		4	1 33 10	−34 29 45	vF, S, R, eF * nr nf.
6		6	1 46 45	−30 26 20	pB, eS, lE, like a D nebulous *. See No. 1.
7		6	1 53 45	−33 46 44	eeeF pS, R, 7m * in field nf, another suspected.
8		4	2 6 0	−33 29 40	vF, S, vE, one * nr.
9		5	2 11 0	−31 41 30	pB, pS, lE.
10		6	2 34 3	−27 52 25	pB, cS, R, 8m * pretty close p.
11		5	2 44 30	−31 42 30	vF, pS, R, 1st of 3.
12		5	2 44 32	−31 36 32	pF, pS, R, 2nd of 3.
13		5	2 45 4	−31 36 32	pF, pS, lE, 3rd of 3.
14	July	22	20 19 10	−31 11 37	eF, pS, lE, wide D * nr s.
15		25	20 20 50	−36 20 57	pB, vS, eE.
16	Aug.	29	20 22 0	−36 22 19	eeS, eE, in meridian.
17		29	20 24 30	−33 50 57	pF, pS, lE.
18		29	20 36 50	−30 11 30	vF, pS, R, 2 F st nr nf point to it, 1st of 3.
19		29	20 37 5	−30 11 30	eeF, cS, eE, 2nd of 3 edif, nr p *, of several in segment of a circle.
20		29	20 37 30	−30 1 30	eeeF, pS, vE, eedif, 3rd of 3.
21	July	9	21 26 5	−37 9 9	eF, pS, R, an e wide D * f 30s.
22	Aug.	31	22 3 5	−28 21 11	eeF, vS, vE, right angled triangle with 2F st near.
23		8	22 36 0	−45 19 15	pF, pL, R, F * nr sf.
24	Sept.	4	22 51 10	−37 7 5	eeF, vS, eeeE, a ray, almost a line, np of 1459 Index Cat. Barnard.
25		4	22 52 20	−36 35 2	vF, vS, R, sf of 2.
26		4	22 52 30	−36 24 0	pB, pS, R, np of 2.
27	Aug.	8	23 13 50	−42 49 45	eeF, S, cE, f of 3, f 7599.
28		8	23 16 18	−43 3 20	eeeF. pL, R, 10m * nr sp, 11m * f, eedif.
29		8	23 23 8	−42 2 0	pB, pS, R, 9m * close S.
30		8	23 26 59	−45 36 18	vF, vS, R, bet 2 st, 8m * sp.

Note on Observations of Venus in 1897 (January to April) *at Mr. Crossley's Observatory, Bermerside, Halifax.* By Joseph Gledhill.

Venus was carefully examined on every clear day, always long before sunset, and a list of the many markings, &c., which have been seen by observers, on the terminator near the poles and on the general surface of this planet, was prepared. It was, therefore, somewhat distressing to have to confess day by day that none of these projections, &c., on the terminator, dark or bright areas on the general surface, bright polar caps, &c., were ever seen with certainty, although the new glass gave an image of wonderful purity and sharpness. It ought, perhaps, to be said that on no occasion was the steadiness of the image at all what could have been desired.

The following notes will show the nature of the impressions actually received when the planet was examined under fairly good conditions :—

1897 January 26. 3 P.M. Cloudless sky; much motion. The full limb is brightest in the *n p* quadrant, and this brightness extends into the *s p* quadrant a good way. Terminator convex. The S. cusp is not like the N. ; it has a kind of hook or projection, while the N. cusp is flattened. The contrast between the bright portion of the full limb and the rest of the surface is very marked. The peculiar form at the S. cusp has been noticed several times lately. 4 P.M. The brightest part of the full limb is about the middle of the *n p* quadrant. The interior of the disc is much less bright than the terminator or the full limb.

January 27. 3 P.M. Cloudless. The full limb is very bright; brightest in *n p* quadrant, about the middle of it.

February 7. 4 and 5 P.M., just before and soon after sunset. The full limb is brightest in the *n p* quadrant. At the S. cusp there is a small rounded form or boss.

Observations of the Physical Features of Mars, made at Mr. Crossley's Observatory, Bermerside, Halifax, during the Opposition 1896–97. By Joseph Gledhill.

These observations were made with the 9-inch triple object glass mentioned in the following paper on *Jupiter*.

1896 December 19. $\lambda = 127$. The planet was carefully examined, but the only features that could be distinctly seen and identified were a broad dark band surrounding the S. pole ending in a darker point or apex ; the faint circular patch to the W.

Terby Sea no doubt; and a faint, narrow, dusky curve sweeping round the E. side of Terby Sea at a distance from it about its own diameter away. This was probably Bessel Lake and Copernicus Land combined.

December 28. $\lambda=344°$. The *p* limb very bright; the *f* limb not nearly so bright. A dusky area not far from the S. pole was badly seen; also what was probably Knobel Sea in the *np* quadrant.

1897 January 1. $\lambda=7°$. A dusky, broad area or band lay to the N. of the S. pole and extended to nearly the centre of the disc (Herschel II. Strait, &c.), and having the three horn-like and curved projections at its N. edge just to the W. of the centre; these are Dawes' Forked Bay and Burton Bay. Near the *f* limb lay Knobel Sea; and, a mere faint speck, Lassell Sea in the *np* quadrant, not far from the limb. The *p* limb was not so bright, but still much brighter than the *f* limb. The S. limb was the brightest portion. The three bays were the darkest markings on the disc and were quite conspicuous.

January 2. $\lambda=344°$. The W. limb was not very bright, but much brighter than the E. or *f* limb. The S. portion of the Kaiser Sea could be seen quite up to the W. limb.

January 13. $\lambda=279°$. The one conspicuous feature was the N. portion of the Kaiser Sea. The region round the S. pole was bright (Lockyer Land, &c.). A soft warm colour lay over the regions E. and W. of the Kaiser Sea; and a narrow dusky curve was seen round the N. pole, which was perhaps Delambre Sea. When $\lambda=231°$ there was a soft rose colour over all except the N. polar cap and the region near the W. limb. The W. limb was much brighter than the E. A dusky patch was seen just S. of the N. polar cap, and another near the W. limb where Oudemann Sea lies. The Kaiser Sea lies near the E. limb, and there is a bright narrow strip along its W. edge. When $\lambda=186°$ a dusky broad band lies across the disc to the N. of the S. pole, and there are also some faint markings to N. of it. The bright strip along the W. limb is very bright and broad, perhaps one-fourth or one-fifth of the semi-diameter. On the E. side of the disc the colour extends quite up to, or very nearly to, the limb. The W. limb is bright from pole to pole and much brighter than the E. limb. The broad band to N. of the S. pole is Maraldi Sea, &c.; the faint markings to N. of it are Oudemann Sea, &c.

When $\lambda=230°$ there was no trace of ruddy colour on the disc, power 150; power 240 revealed a slight warm tint. The W. limb was not much brighter than the E., and a bright division in the dark region round the S. pole can be seen; it is probably Burckhardt Land. A bright spot is seen just to E. of Oudemann Sea, which is probably Fontana Land.

January 14. $\lambda=188°$. A broad band lies across the disc to N. of S. pole; it is Maraldi Sea; the polar region to the S. of it is not bright; the W. limb is very bright, and the E. limb less so; there is a warm tint over the central region; in the *nf*

quadrant Oudemann Sea is seen, and a bright circular spot just E. of it, *i.e.*, Fontana Land; Oudemann Sea was on the central meridian about 6 P.M. The warm central tint extends quite up to the E. limb, but not to the W. limb.

January 17. $\lambda=179°$. The faint red colour does not extend up to the E. limb, and stops a good way short of the W. limb. The W. limb is brighter than the E., but not strikingly so.

$\lambda=192°$. W. limb not at all bright; very little colour on the disc. Oudemann Sea was central about $7^h\ 35^m$.

$\lambda=237°$. A dark narrow patch lies just S. of the N. polar cap. The Kaiser Sea is near the E. limb and is faint. In the *sp* quadrant, just under the broad band and near where the N. edge of this band touches the W. limb, there is considerable ruddy colour.

$\lambda=267°$. The Kaiser Sea is dark; no red colour on the disc; W. limb not very bright.

January 18. $\lambda=184°$. Central region pale red; no colour between Oudemann Sea and the E. limb; W. limb not very bright; Oudemann Sea in *nf* quadrant. When $\lambda=198°$ red colour was seen on both sides of Oudemann Sea; W. limb very bright, much brighter than the E. limb; Oudemann Sea on the central meridian about $8^h\ 12^m$. When $\lambda=257°$ Kaiser Sea was well away from the E. limb.

January 20. Nasmyth Inlet has not yet been seen this opposition; Lassell Sea has been well seen more than once; the dark Bessel Lake and the dark sweep to the north of it, and that to the N. of Copernicus Land, have been seen once; Trouvelot Bay has been seen several times since 1896 December. This evening, $\lambda=193°$, the broad band to the N. of the S. pole, a faint diffuse marking between the centre and the N. pole (Oudemann Sea), and the N. polar cap are well seen. Oudemann Sea was on the central meridian about $9^h\ 20^m$. Very little ruddy colour seen on the disc.

January 21. $\lambda=193°$. The *p* limb is not very bright, and is not much brighter than the *f* limb; very little, if any, warm colour on the disc. The region S. of Maraldi Sea is bright, and Burckhardt's Inlet is seen. A faint marking near the *p* limb is seen; it is probably Oudemann Sea.

January 22. $\lambda=160°$. The *p* limb is very bright; the *f* limb is not bright. There is a faint marking in the *np* quadrant. Trouvelot Bay is near the central meridian. The region S. of the great broad band S. of the centre is bright. The N. polar cap is bright.

January 23. $\lambda=173°$. The N. polar cap is well seen; it is small, bright, and a little brighter than the *p* limb; the *f* limb is not bright. There is a rosy glow all over, the disc to the N. of the broad band between the S. pole and the centre. The region (polar) between this broad band and the S pole is nearly as bright as the central parts of the disc. There is a very bright spot on the S. limb some 20° to the W. of the point where a line through

the N. polar cap, and the centre of the disc would cut the S. limb; it is like a bright white bead and smaller than the N. polar cap. The dark broad band to N. of S. pole is Maraldi Sea, &c. Trouvelot Bay is seen occasionally. The bright spot just named lies on the S. edge of the broad band and just where it reaches the West limb.

January 25. $\lambda=90°$. The polar region between Maraldi Sea, &c., and the S. pole is bright. The W. limb is not very bright. When $\lambda=119°$ Maraldi Sea is very faint. No markings to the N. of Maraldi Sea can be seen distinctly.

January 26. $\lambda=82°$. The W. limb not very bright; no red colour on disc; brightness of W. limb extends beyond the N. pole. When $\lambda=126°$ the W. limb was bright yellow, not white; E. limb not so bright; Maraldi Sea very faint; the region between it and the S. pole is bluish white. The darkest marking is just well on the disc in the *sf* quadrant (Trouvelot Bay ?). The S. polar cap is seen. When $\lambda=140°$ the region near the S. pole is the brightest part; it is bluish white. Maraldi Sea and adjacent regions E. and W. are faint. The W. limb is very bright.

February 7. $\lambda=351°$. N. polar cap very bright; a faint curve is seen round the S. edge of the cap (Schrœter Land ?). Dawes' Forked Bay and Burton Bay seen as one curved horn ? Lockyer Land, very bright, in *sp* quadrant in the polar area and close to limb ? One edge of the Kaiser Sea very near the W. limb ? The *p* limb much brighter than the *f* limb.

February 9. $\lambda=91°$. The N. polar cap is well seen. The limb in the *sp* quadrant is very bright; that in the *np* quadrant less so. The S. polar region is dusky. The width of the bright strip within the W. limb is about $\frac{1}{4}$ of the semi-diameter of the disc. A dark horn on N. edge of the broad dark band was on the central meridian about $8^h\ 35^m$.

February 16. $\lambda=286$. The N. portion of the Kaiser Sea was central about $7^h\ 51^m$. The *p* limb was bright but not very bright; the *f* limb dull. The N. polar cap was well seen. Lockyer Land, near the S. pole, was bright and bluish white. A dusky curve just S. of the N. polar cap was easily seen. Nasmyth Inlet and Lassel Sea are not seen.

February 23. $\lambda=220°$. The *p* limb is very bright, and much more so than the *f* limb. The region round the S. pole is bright, and the N. polar cap is seen, but no other markings with the exception of the broad dark band to N. of the S. pole, *i.e.*, Maraldi Sea, &c.

February 27. $\lambda=182°$. The region between Maraldi Sea and the S. pole is nearly as bright as the N. polar cap. The broad, dark band (Maraldi Sea, &c.) is darkest near the *f* limb. Nothing definite can be seen in all the region between Maraldi Sea and the N. pole. The *p* limb is very bright and the brightness extends inwards $\frac{1}{4}$ or $\frac{1}{5}$ of the radius of the planet; the *f* limb is much less bright.

March 1. $\lambda=192°$ The p limb is much brighter than the f limb. A faint line of shading is seen on S. edge of the N. polar cap.

March 8. $\lambda=86°$. The p limb is very bright, and the brightness extends inwards about $\frac{1}{8}$ of the semi-diameter of the planet. The only other marking is the dusky, broad band to N. of S. pole stretching all the way across the disc.

March 10. $\lambda=67°$. The p limb is very bright and the brightness extends inwards as on the 8th. The dark band across the disc (De la Rue Ocean, &c.) is, as it nearly always is, the most prominent feature of the disc; the region between it and the S. pole is very bright. There is a dusky form near the centre of the disc; Airy Sea? And one near the p limb; Knobel Sea? The N. polar cap is bright and small.

March 13. $\lambda=68°$. Knobel Sea (?) is seen as on the 10th, but not Airy Sea. The N. polar cap is bright, so is the area near the S. pole. The p limb is much brighter than the f limb.

March 16. $\lambda=10°$. The p limb is bright and brighter than the f limb. Knobel Sea is on or near the central meridian, and is a faint, diffuse marking. The broad band to N. of the S. pole (De la Rue Ocean, &c.) is darkest near the f limb, and becomes pale near the p limb. The N. polar cap is bright. The area near the S. pole is bright.

Notes.

1896 December 19. Fair definition. December 28. Very poor seeing. 1897 January 1. Fair. January 2. Very poor. January 13. Fair; often good for a few moments. January 14. Fair. January 17. Bad. January 18. Much motion. January 20. Fair. January 21. Violent motion. January 22. Stormy; good definition between showers of snow. January 23. Fair. January 25. Bad. January 26. Bad. February 7. Poor. February 9. Poor. February 16. Fair. February 23. Stormy; bad. February 27. Poor. March 1. Poor. March 8. Poor. March 10. Fair. March 13. Bad. March 16. Fair.

Observations of Jupiter and Jupiter's Satellites made at Mr. Crossley's Observatory, Bermerside, Halifax. By Joseph Gledhill.

This paper comprises the following sub-divisions :—

(*a*) A description of the principal features seen on the disc of *Jupiter* from 1896 November to 1897 June.

(*b*) Transits of dark and bright spots.

(*c*) The red spot, &c., notes and transits.

(*d*) Measures of the position of the principal dark belts.

(*e*) Measures of the breadth of dark bands and bright zones.

(*f*) Measures of dark and bright spots, &c.

(*g*) Notes on satellites and shadows during transit across *Jupiter's* disc.

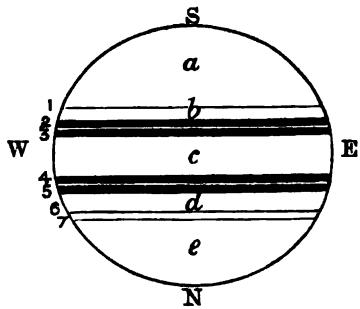
(*h*) Observations of phenomena of *Jupiter's* satellites.

The observations were made with a 9-inch object-glass—one of the new triple lenses by Messrs. T. Cooke and Sons, York. This glass has replaced the $9\frac{1}{3}$-inch objective used for so many years at this observatory. It was expected that with this new object-glass we should obtain a purer image and see more detail on such planets as *Jupiter* and *Mars*. Nor have our expectations been unfulfilled. The instrument was turned to these planets on every fine night during the winter and spring, and the views when the definition was good certainly surpassed everything we had seen in past years with the $9\frac{1}{3}$-inch glass; the image was as pure and soft and free from colour as that given by a good reflector.

When negative eye-pieces were used the powers were 240 and 330; and a power of about 300 when the micrometer measures were made.

(*a*) *Description of the Principal Features seen on the Disc of Jupiter from* 1896 *November to* 1897 *June.*

In order to avoid confusion and save much repetition the annexed diagram is given. The dark lines represent the dark



bands or belts, and the spaces between them are the bright zones. No. 1 is the narrow strap-like dusky band, the S. temperate band; 2, 3 together form the remarkable broad dark S. equatorial belt; 4, 5 together form the broad dark N. equatorial belt, a feature nearly as conspicuous as 2, 3, and quite as interesting; 6 is a rather faint narrow band; 7 is still less dark than 6, and never seen perhaps except when the observing conditions were really good. Detached portions of a faint dark belt in the central zone (the equatorial zone) will be described, but they were rarely well seen.

a is the bright S. polar area, *b* the S. tropical zone, *c* the equatorial zone, *d* the N. tropical zone, and *e* the N. polar area.

1.

(λ is the longitude of the central meridian at the time of the observation.)

1896 November 14. $\lambda = 183°$. 1 is a narrow band, not dark.

1897 January 13. λ=188°. 1 is a faint and narrow band.

February 22. λ=67°. 1 is a faint and narrow band. As this description is of general application to 1 it will not be repeated; special departures from it alone will be noted.

March 1. λ=354°. There is a small, bright circular spot on 1; it is on the central meridian, $10^h\ 15^m$.

March 10. λ=204°. 1 is rather broad, say about the breadth of 2, 3 (taken as one belt); it is pale blue in colour.

March 13. λ=19°. A small bright, circular spot seen on 1, on the central meridian at $10^h\ 49^m$; another similar spot lies on 1 more than half way to the *p* limb. They look like satellites in transit.

March 16. λ=8°. 1 begins to grow darker a little to the W. of the *p* end of the red spot.

March 19. λ=199°. 1 is a strap-like band; well seen.

March 21. λ=39°. 1 is broad and fairly dark.

March 25. λ=245°. 1 is almost a conspicuous marking.

March 31. λ=173°. 1 is a broad, parallel-sided band and very well seen.

April 4. λ=8°. 1 begins to be darker just above the *p* end of the red spot (see March 16). λ=38°: The darker part of 1 extends from the longitude of the *p* end of the red spot to a point a little to the right of the *f* end, and then again becomes faint.

April 5. λ=134°. 1 is broader than either 2 or 3, or than either 4 or 5. λ 325° to λ 343°: The belt is narrower.

April 22. λ=132°. The preceding $\frac{1}{3}$ of 1 is darker and broader than the following $\frac{2}{3}$.

April 23. λ=282°. 1 is faint; so also when λ=319°.

April 27. λ=200°. 1 is grey.

April 28. λ=349°. The S. edge of 1 has a wavy outline; there are several small, bright, circular spots on it.

April 30. λ=90°. A small bright spot on the S. edge of 1 has passed the central meridian.

May 1. λ=80°. 1 is not well marked; darkest in middle portion. λ=116°: 1 begins to be broader and darker.

May 3. λ=39°. 1 has a darker and wider portion just above the red spot (*i.e.*, to S. of it), then faint and narrow for an equal length, and then darker up to the *f* limb. λ=77°: 1 begins to be darker and broader.

May 8. λ=88°. 1 has light and dark portions.

May 10. λ=343°. 1 is faint, except over the red spot.

2, 3.

1896 November 14. λ=183°. A very broad, brownish-yellow,double d ark band; the most salient feature of the disc.

November 19. λ=232°. A double, dark band.

1897 January 13. λ=188°. The darkest and broadest band. So also on January 14; λ=319°. Dark yellow on January 17; λ=34°. On January 18, λ=184°, not dark.

January 21. $\lambda=257°$. The E. half is darker than the W. half. Dark spots on 3 when $\lambda=334°$.

January 23. $\lambda=249°$. Deep yellow in 2, 3. On January 27, $\lambda=98°$, deep yellow to brown in 2, 3.

February 23. $\lambda=199°$. Yellow colour between 2 and 3.

February 26. $\lambda=281°$. 2 and 3 nearly in contact on the W. half; on the E. half the space between them is wider, as also when $\lambda=308°$.

February 27. $\lambda=19°$. Not so dark to the left of the central meridian as to the right. When $\lambda=313°$ the place where the space between 2 and 3 begins to widen is seen.

March 1. $\lambda=239°$. 2, 3 dark yellow; 3 is darker than 2. $\lambda=310°$: The bright space between 2 and 3 begin to widen, 2 getting narrower, 3 unchanged; 2 is not so dark as 3.

March 8. $\lambda=93°$. The place where 2 and 3 begin to widen is seen; at this place 2 begins to be faint.

March 10. $\lambda=306°$. The place where the space between 2 and 3 begins to widen is on the central meridian.

March 13. $\lambda=349°$. The space between 2 and 3 is very narrow. $\lambda=304°$: The place where the space between 2 and 3 begins to widen is now on the central meridian.

March 17. $\lambda=122°$. The belt is both dark and coloured. $\lambda=240°$: 2 is a band of uniform darkness, while 3 is broken up into detached masses.

March 19. $\lambda=99°$. Deep yellow colour on 2 and 3. When $\lambda=199°$ the colour is dark yellow.

March 24. $\lambda=94°$. 2 is as dark, but not so broad, as 3.

March 31. $\lambda=173°$. 2 is not so dark nor so broad, as 3; 3 is broken up into dark cloud forms.

April 4. $\lambda=344°$. 2 is narrow. 3 is nearly as wide again as 2, and darker. $\lambda=2°$: 2 is narrower than 1. $\lambda=8°$: 3 is broken up into dark masses, which project into the central zone. There is a bright canal in 3, *i.e.* a gap in 3 connecting the bright space between 2 and 3 with the central zone.

April 5. $\lambda=134°$. There is a bright spot on 3. When $\lambda=152°$ another bright gap in 3 is seen. $\lambda=170°$: 2 and 3 are well separated, and 3 is broken up into cloud masses. $\lambda=325°$ to $343°$: 2 and 3 are seen as a uniform double band, *i.e.* not broken up or irregular, and with only a few inconspicuous cloud masses on them.

April 7. $\lambda=111°$. 2, 3, together as broad as 4; the *f* half of 2, 3 much wider than the *p* half. Cloud forms on 3 project into the central zone.

April 14. $\lambda=101°$. 2 and 3 separated all the way across the disc.

April 23. $\lambda=282°$. 2, 3 as wide as 4. Just behind (to E. of) the *f* shoulder (the great one), the bright space between 2 and 3 cuts through 3 to the central zone, like a canal running from the central zone into 2, 3, and making one dark belt into two. To the E. of the mouth of this canal 2 becomes narrower and 3 broader.

April 24. λ=109°. 2, 3 separated by a bright narrow zone all the way across the disc. So also on April 27, λ=200°, 2 being nearly as dark and broad as 3.

April 28. λ=325°. 2 becomes suddenly faint, and a bright circular spot is seen on 3.

April 30. λ=257°. 2, 3 separated. λ=272° : 2, 3, together, wider than 4, and 3 is cut through in several places. λ=293° : The place where the space between 2 and 3 widens is on the central meridian. λ=307° : 2 is narrower and paler than 3 from the *p* shoulder to the preceding limb, and gets fainter all the way up to the *p* shoulder.

May 1. λ=80°. 2, 3 separated ; dark cloud forms on 3 project into the central zone.

May 5. λ=321°. 2 is much less dark than 3 and narrower.

May 8. λ=74°. 2, 3 separated.

May 9. λ=207°. There are two bright gaps in 3, like two large eyes.

As during a good many previous oppositions, the principal features of these two broad dark bands are the great shoulder just to the E. of the red spot (called above the *f* shoulder), the less conspicuous shoulder just to the W. of the red spot (called the *p* shoulder above), and the hollow between these two shoulders. At the bottom of this hollow belt 2 has disappeared, and 3 alone remains to connect the two shoulders. At the *f* shoulder the belts 2 and 3 run into one broad dark band ; but a little to the E. the bright canal named above runs in from the central zone and converts the band into two.

4, 5.

1896 November 14. λ=183°. A narrow belt, not darker than 1. November 19. λ=232°. Very faint.

1897 January 17. λ=34°. A dark belt, consisting of detached portions six or eight in number, has been formed in the latitude of the two dark spots seen throughout the last opposition.

January 18. λ=184°. A fairly dark and sharp band ; the *p* half is detached from the *f* half, and is the darker of the two ; the *f* half has a small dark spot on it. January 21. λ=257°. There are dark spots on E. half. January 23. λ=249°. It is broken up into detached cloud forms.

January 27. λ=98°. It is narrow ; 4 is narrow and continuous ; 5 is broken up ; 5 is the darker band. The band 4 begins to fade away on the central meridian, and the zone it lies in becomes clear ; λ=122°.

February 16. λ=117°. Widely double on the W. half ; then single

February 22. λ=67°. As broad as 2, 3 ; broken up ; the detached portions (dark cloud forms) project into the central zone.

February 23. λ=118°. Broken up (*i.e.* 5); the *p* half of 4, 5 is as broad as 2, 3; the *f* half is narrower and broken up. With λ=199° 4 is very faint, and 5 has dark cloud forms on it, or is broken up into dark pieces.

February 26. λ=308°. Broken up; so also February 27, λ=80°.

March 1. λ=239°. 4, 5 much fainter than 2, 3; no colour (yellow) in it; broken up.

March 3. λ=249°. Broken up; bluish; as broad as 2, 3.

March 8. λ=54°. Broken up. March 9. λ=72°. Broken up; nearly as dark as 2, 3 to the E. of the central meridian. March 10. λ=186°. Broken up and bluish. March 16. λ=8°. 4, 5 broader than 2, 3. March 17. λ=122°. 4, 5 broad, bluish, not dark. When λ=240° broken up, and as dark as 2, 3 nearly. March 19. λ=99°. Broken up; grey. λ=199°. Grey; as wide as 2, 3. March 18. λ=299°. Same colour and width as 2, 3.

March 25. λ=245°. Broader than 2, 3; broken up.

March 29. λ=162°. Broken up; grey. March 31. λ=173°. Broken up, and as broad as 2, 3.

April 4. λ=344°. As wide as 2, 3. With λ=2° 4, 5 is not at all a striking feature of the disc.

April 5. λ=134°. Many square-shaped cloud forms on S. edge of 4, while 5 is little disturbed. With λ=325° the belt is double all the way across the disc. λ=325° to λ=343°: Very little broken up, double, and as wide as 2, 3.

April 7. λ=111°. Broken up, and the dark detached portions project into the central zone. Double all the way across the disc when λ=111°−120°.

April 15. λ=212°. Two bright, small spots on the S. edge of 5. April 14. λ=101°. 4, 5 as wide as 2, 3, but not so dark. April 22. λ=132°. As wide as 2, 3.

April 23. λ=282°. Double; 4 is much broken up; 5 is but little disturbed. With λ=357° a bright V-shaped gap is seen in 4. With λ=37 belt 4, 5 is not so dark as 2, 3. April 24. λ=109°. 4, 5 separated all the way across the disc.

April 26. λ=19°. 4, 5 double all across the disc; and the N. edge of 5 is an undulating line. In λ=158° 4, 5 as dark as 2, 3.

April 27. λ=200°. Many cloud forms on the S. edge of 5. The belt 4, 5 is double all across the disc; dark cloud forms lie on it from the central meridian to the *f* limb, and project into the central zone.

April 28. λ=325°. 4 is cut into two parts by a narrow bright space or gap, and this place is now central; 4 is much darker than 5. There are bright spots on 5.

April 30. λ=257°. 4, 5 double all across the disc; *i.e.* they are separated by a very narrow bright space. λ=309°: The E. half of 4 is continuous; the W. half is broken up.

May 1. λ=80° double; dark cloud-forms on S. edge of 4 and on the N. edge of 5.

May 3. $\lambda=2°$. Double all across the disc; N. edge of 5 irregular in outline. In $\lambda=2°$ to $\lambda=39°$ double; no striking cloud forms on 4 or 5. When $\lambda=77°$ a row of dark oblong spots seen on S. edge of 4.

May 5. $\lambda=321°$. The abrupt ending of 4 is approaching the central meridian; broad; double.

May 8. $\lambda=74°$. Dark spots on the S. edge of 4; double all across the disc.

May 9. $\lambda=207°$. As broad as 2, 3, and as dark. The abrupt ending of 4 was on the central meridian when $\lambda=249°$.

6.

1896 November 14. $\lambda=183°$. Broader and darker than 1 or 4, 5.

1897 January 13. $\lambda=188°$. Fairly dark. March 1. $\lambda=239°$. The short, dark portion of 6 was near the central meridian; it was on the central meridian at about $8^h\ 8^m$; its length is about one quarter the length of the whole band. March 3. $\lambda=249°$. Narrow. March 9. $\lambda=126°$. Rather wide. March 19. $\lambda=199°$. Faint and narrow. March 25. $\lambda=245°$. Difficult to see. March 31. $\lambda=173°$. Fainter and narrower than 1. April 5. $\lambda=134°$. Distinct, narrow, and darker than 1.

April 7. $\lambda=111°$. A short, darker portion of this band was on the central meridian about $9^h\ 20^m$.

April 14. $\lambda=101°$. Difficult.

April 23. $\lambda=285°$. The short, darker portion of 6 is about half-way to the central meridian. The band was very faint and narrow from 9^h to 10^h.

April 27. $\lambda=336°$. Band 6 is now fairly dark all the way across the disc.

April 28. $\lambda=325°$. The short, darker part of 6 is now mid-way between the central meridian and the *f* limb.

April 30. $\lambda=305°$. The darker short piece is now central; its length is about 6″. The band becomes very faint to E. of this darker piece.

May 1. $\lambda=80°$. Very faint. So also on May 3. $\lambda=23°$.

May 5. λ about 303°. The short, darker piece not far from the central meridian at $7^h\ 30^m$.

A faint, narrow band was also occasionally seen just to N. of 6.

Within the central coloured zone *c* portions of a faint band were seen when definition was good; *e.g.* 1897 April 27. $\lambda=181°$. A faint, dusky, narrow belt is now seen ($7^h\ 30^m$) close to the central meridian; it is nearer 3 than 4. Detached portions of it were seen all the way across the disc at $8\frac{1}{2}^h$. On May 8, at $8^h\ 48^m$, portions of this band were seen near the central meridian. And again at $8^h\ 30^m$ on May 9 it was seen nearly all the way across the disc.

The Polar Regions a and e.

Of these it is only necessary to make the remark that *a* was perhaps always nearly as bright and as free from colour as the brightest zone of the disc, viz. *b*; while *e*, the region near the N. pole beyond band 7, was often of a pale yellow colour. A few extracts from the note-book are here given:—

1896 November 14. $\lambda=183°$. "The yellowish region between 6 and the N. pole." November 19. $\lambda=232°$. "*a*, bright, no colour; *e*, a yellow region." 1897 January 13. $\lambda=188°$. "*e*, a brown region." February 16. $\lambda=117°$. "*e*, pale yellow." April 27. $8^h\ 40^m$. "The yellow colour extends from the S. edge of 2 right to the N. pole; but there is very little in zone *d*." And "from the S. edge of 2 to the S. pole there is perhaps no yellow colour." May 8. $\lambda=74°$. "The N. polar area is much more dusky than the S."; and at 9^h ($\lambda=88°$) "a pale yellow colour is spread over the N. polar area." May 9. $\lambda=211°$. "The N. polar area is as free from colour as the S."

The Bright Zones b and d.

1897 January 13. $\lambda=188°$. *b* is bright, but less so than *d*. The same on January 23; $\lambda=249°$. February 22. $\lambda=67°$. *b* is the brightest zone; so also on March 10, 17, April 7, 27, 30; May 3, 10; June 14. But *d* was the brightest on 1896 November 14, when $\lambda=183°$.

The Central (Equatorial) Bright Zone c.

This zone, with the two pairs of dark belts bounding it, was always the most salient feature, and its beautiful yellow colour added much to the effect.

1896 November 14. $\lambda=183°$. "Pale yellow gradually deepening up to band 3; it is also mottled." 1897 January 23. $\lambda=249°$. Deep yellow in and close under (to N. of) 2, 3. And at 11^h ($\lambda=98°$) on January 27, 2, 3 deep yellow to brown. March 1. $\lambda=239°$. The yellow colour gets paler from 3 to 4; is deepest just on the N. edge of 3, and stops short of 4. March 10. $\lambda=186°$. As on the 1st, no colour in the zone *c* close to the S. edge of 4. March 17. $\lambda=122°$. The deep yellow of *c* extends to the S. edge of 2 and gets paler towards 4. March 19. $\lambda=199°$. *c* and 2, 3 dark yellow. March 24. $\lambda=94°$. As on the 1st. March 31. $\lambda=173°$. *c* full of yellow colour. April 2. $\lambda=80°$. Little yellow colour in *c*. April 4. $\lambda=2°$. No yellow in the narrow zone between 2 and 3; *c* as on March 1.

April 23. $\lambda=37°$. *c*, and also 3, yellow; so also on April 24; $\lambda=109°$. April 27. $\lambda=199°$. The yellow of the zone *c* extends to and covers 2 and 3; the colour is deepest close under (to N. of) 3. April 30. $\lambda=275°$. Most of the colour is close to 3, but does not extend to 2. May 3. $\lambda=80°$. *c* is full of colour.

(*b*) *Transits of Dark Spots on the Belts.*

No well defined, isolated dark spots were seen in the bright zones, and very few on the dark belts; indeed, perhaps not one calling for any special note. The times of transit over the central meridian were noted in all cases when the definition was sufficiently good.

1896 November 14. A long dark spot or local darkening of 4, 5 was on the central meridian about $5^h\ 57^m$ A.M. On 1897 January 17, belt 4, 5 was broken up into spots or large detached portions; one was on the central meridian about $11^h\ 22^m$, another at $11^h\ 54^m$, and a third about $12^h\ 27^m$. January 18. A dark spot was seen on 4, 5 at $12^h\ 20^m$; it lay between the central meridian and the *f* limb. January 21. About $12^h\ 37^m$ one of the dark cloud forms on 4, 5 was on the central meridian; other dark detached cloud masses lay to right and left along the belt. January 23. About $11^h\ 20^m$ a dark mass was on the central meridian. February 22. $\lambda=67°$. Large dark cloud forms or spots lay along 4, 5 and projected into zone *c*. So also on February 23; one being on the central meridian about $8^h\ 47^m$, and another at $10^h\ 50^m$. February 26. $\lambda=281°$. 4, 5 a series of dark cloud forms all the way across the disc. So also on February 27; $\lambda=8°$ and $\lambda=20°$ and $\lambda=80°$. March 1. $\lambda=239°$. The dark masses lay on 4 and projected into zone *c*; one was on the central meridian about $7^h\ 49^m$, another about $8^h\ 2^m$, another at $10^h\ 47^m$. March 9. $\lambda=72°$ and $\lambda=126°$. 4, 5 was a series of dark masses. March 13. A dark mass on 4, 5 was on the central meridian about $10^h\ 15^m$. March 17. $\lambda=240°$. Dark masses on 4, 5 all along the belt and projecting into the *c* zone. So also on March 29, $\lambda=162°$; March 31, $\lambda=173°$; April 7, $\lambda=111°$. On April 23, $\lambda=285°$, 4 was broken up into dark masses projecting into the *c* zone. On April 27 a prominent cloud mass was seen on the S. edge of 4; it was on the central meridian about $7^h\ 55^m$; others lay to the E. and W. of it on 4. At about $8^h\ 34^m$ a dark, circular spot, 1″ in diameter, was seen on the S. edge of zone *b* and on the central meridian.

On May 1, about $9^h\ 5^m$, a dark form on the S. edge of 4 was on the central meridian; many others lay on the same belt; one was on the central meridian about $10^h\ 25^m$. On May 3 the first of a series of dark masses on the S. edge of 4 was on the central meridian at $9^h\ 52^m$, another at $10^h\ 29^m$. May 6, at $7\frac{1}{4}^h$, 4 was a series of dark masses. May 8. One of the dark masses on 4 was on the central meridian about $8^h\ 37^m$, another at $8^h\ 59^m$, a third about $9^h\ 47^m$, and a fourth about $10^h\ 41^m$.

The dark belts 2, 3, were less disturbed than 4, 5. 1897 February 23, at 9^h, two dark forms were seen on 3. On March 8, at $8\frac{1}{2}^h$, belt 3 was a series of detached cloud forms; so also on March 17 at 7^h.

April 4, at $8^h\ 40^m$, the detached portions of 3 projected into the *c* zone; so also on April 7 at 9^h, and on April 28 at $7\frac{1}{2}^h$, and

May 1 at 8^h. At 8^h on May 9 two dark spots lay on 3 between the central meridian and the *f* limb; one was on the central meridian about $8^h\ 29^m$ and the other about $9^h\ 19^m$. On May 11 a dark spot on 3 was on the central meridian about $9^h\ 45^m$. On June 12, about $9^h\ 17^m$, a dark spot on 3 was on the central meridian.

Transits of Bright Spots.

1897 March 1. A small, bright, circular spot lay on the S. edge of 4 and was on the central meridian about $8^h\ 48^m$. At $10^h\ 15^m$ a similar spot on belt 1 was on the central meridian. The diameter of these spots was about 1″. March 13. A small, bright spot on belt 1, on central meridian about $10^h\ 49^m$. March 16. A small, bright spot between 2 and 3, just to E. of the central meridian, at 11^h. April 4. A bright, circular spot lay just under (to N. of) 5; on central meridian about $8^h\ 35^m$. A similar spot lay on the S. edge of 4; on central meridian about $9^h\ 12^m$.

April 5. A bright, circular spot close under 3 in bright zone *d*; on central meridian about $8^h\ 2^m$. This spot was much larger than the others.

April 15. A small, bright spot on the S. edge of 4 had just passed the central meridian at 8^h; another, on the same parallel, was on the central meridian about $8^h\ 25^m$. April 23. A bright, circular spot on belt 1 was on the central meridian about $9^h\ 7^m$. April 28. A small, bright, circular spot on 1 had passed the central meridian at $7^h\ 30^m$. Indeed, several small, bright, round spots were seen on belt 1. One on the dark belt 5 was on the central meridian about $7^h\ 45^m$. Another on the S. edge of 1 was on the central meridian at $8^h\ 10^m$. Another on the N. edge of 3 was also seen, and it was on the central meridian about $8^h\ 27^m$.

April 30. A small, bright, round spot on the S. edge of 1 had passed the central meridian at $8^h\ 15^m$. Another on the same belt was on the central meridian about $8^h\ 45^m$.

May 9. Two bright gaps in dark belt 3, looking like a pair of eyes, were a conspicuous feature at $8^h\ 9^m$. A narrow, dark strip of belt separates them; the *f* one was on the central meridian about $8^h\ 15^m$. They were seen again on May 11, and were on the central meridian about $9^h\ 18^m$.

A bright wedge, or V-shaped gap, in dark belt 4 was a conspicuous object on April 23; it was on the central meridian about $9^h\ 4^m$.

May 3. A small, bright spot on 1 was on the central meridian about $7\frac{1}{4}^h$.

(*c*) *The Red Spot, the Trough, and the two Shoulders.*

These remarkable and very permanent features call for some little notice. Of the red spot it may at once be said that, as seen here, there is no red or other distinctive colour about it, and that

'the ellipse' would be a more suitable designation. On even the best nights this wonderful object was never really well and steadily seen. The *f* end of the outline was the darkest and broadest portion; the *p* end was rarely well seen; the whole outline of the ellipse was rarely seen, owing to the faintness of the N. and S. portions. On one occasion some very faint line or marking parallel to the belts was with difficulty seen within it. The *f* end is perhaps just in contact with the great or *f* shoulder. The following transits were obtained, but with difficulty and uncertainty:—March 13, $10^h\ 51^m$; March 16, $8^h\ 22^m$; April 4, 9^h; April 16, 9^h; April 30, $10^h\ 25^m$; May 3, $7^h\ 51^m$; May 5, $9^h\ 26^m$; and May 10, $8^h\ 38^m$.

The p shoulder was on or very near the central meridian on February 27, 9^h; March 1, $10^h\ 42^m$; March 13, $10^h\ 18^m$; April 23, $9^h\ 15^m$; May 3, $7^h\ 29^m$; May 5, 9^h; May 10, $8^h\ 10^m$; April 28, $8^h\ 20^m$. *The middle of the trough* between the two shoulders was on or near the central meridian February 27, $9^h\ 18^m$; March 1, $10^h\ 55^m$; March 13, $10^h\ 45^m$; March 16, $8^h\ 15^m$; April 23, $9^h\ 40^m$.

The f or great shoulder was on or near the central meridian February 27, $9^h\ 46^m$; March 21, 8^h; April 4, $9^h\ 25^m$; April 23, $10^h\ 10^m$; April 26, $7^h\ 42^m$; April 30, $10^h\ 50^m$; May 3, $8^h\ 24^m$.

These transits were eye estimations, and none were regarded as satisfactory, owing to the bad atmospheric conditions prevailing at the time. They seem to point to a considerable change in the longitude of these features.

(*d*) *Measures of the position of the principal belts.*

The method adopted was that described in full on page 478, volume 56, of the *Monthly Notices*. The value of one revolution of the micrometer screw is, with the new 9-inch object glass, 13″·525: one division of the divided head = 0″·135. And a power of nearly 300 was always used.

As an illustration of the values of the polar diameter of *Jupiter* obtained by measuring the distance of a dark band from the two poles, and therefore also of the degree of accuracy of the resulting latitudes of the bands, the following values of the polar diameter 1897 March 10 are given:—

1897.		Diff. from mean.	1897.		Diff. from mean.
Mar. 10	41″·9	0″·0	Mar. 10	41″·1	−0″·8
	41·5	−0·4		40·9	−1·0
	42·6	+0·7		42·5	+0·6
	42·5	+0·6		41·9	0·0
	41·9	0·0		41·7	−0·2
	42·7	+0·8			
	Mean of all = 41″·9		Mean diff. 0″·5.		

Computed polar diameter for noon of Mar. 10 from Mr. Marth's ephemeris = 42″·2.

Dark Band 1.

The measurements were made from the middle of this strap-like band to each pole. Column *a* gives the longitude of the central meridian, and *b* the latitude, computed by Mr. Marth's formula.

1897.	*a* °	*b* °	1897.	*a* °	*b* °
Mar. 10	295	−25	Apr. 23	319	−27
13	313	−24·8	26	85	−29·3
27	322	−27	27	217	−28·8
Apr. 8	225	−26·2	30	290	−27·6
8	243	−28·1	May 1	80	−27·2

Mean −27°·1 1895–6 −29°·4.

Dark Band 2, 3.

The measurements were made from the bright space between the two bands to each pole.

1897.	*a* °	*b* °	1897.	*a* °	*b* °
Mar. 10	295	− 8·6	Apr. 8	243	−12·0
13	313	−10·2	15	197	−12·5
16	81	−11·4	23	319	−13·1
18	309	−10·0	24	109	−10·5
19	135	− 9·7	26	19	−10·9
23	340	− 9·0	27	199	−12·7
25	281	−10·0	28	331	−11·9
27	322	−11·5	30	257	−12·3
Apr. 4	344	− 9·8	May 1	44	−12·3
4	20	−11·4	3	356	−11·1
2	80	−10·4	5	320	−11·6
8	225	− 9·7			

Mean −10°·9 1895–6 −13°·1.

Dark Band 4, 5.

1897	*a* °	*b* °	1897.	*a* °	*b* °
Mar. 10	295	+10·7	Apr. 8	225	+12·6
13	313	+ 9·3	8	243	+14·6
16	81	+13·9	15	197	+15·5
18	309	+ 9·7	23	319	+14·1
19	135	+10·3	26	85	+13·6
25	281	+11·7	28	350	[+18·3]
Apr. 2	80	+11·7	30	290	[+18·9]
4	344	+10·4	May 3	356	+12·6
4	20	+12·5	5	320	+13·8

Omitting the values in brackets, mean +12°·3. 1895–6 +8°·3.

The S. Edge of Dark Band 2.

1897.	*a*	*b*	1897.	*a*	*b*
Mar. 10	295°	−12°·8	Apr. 26	85°	−19°·9
13	313	−15·0	27	217	−19·3
25	281	−16·0	28	350	−18·2
27	322	−20·1	30	290	−18·4
Apr. 4	344	−16·5	May 1	80	−19·6
8	225	−15·7	3	5	−19·1
15	197	−17·6	5	321	−17·4
23	319	−16·9	6	75	−19·9

Mean −17°·6.

The N. Edge of Dark Band 5.

1897.	*a*	*b*	1897.	*a*	*b*
Mar. 10	295°	[+12°·0]	Apr. 26	85°	+20°·6
16	81	+18·9	27	217	+17·9
25	281	+18·5	28	350	+22·1
27	322	+16·2	30	290	+22·2
Apr. 4	344	+16·5	May 1	80	+19·6
8	243	+21·1	3	8	+19·3
15	197	+20·9	5	321	+21·7
23	319	+21·7	6	75	+19·9
24	108	+20·8			

Mean +19°·8.

A few measures on good nights were taken by placing a web so as to bisect the central zone *c*, and placing the other web tangent to the poles in succession.

March 10, λ=295°; middle of zone *c* to S. pole=21″·84 and 21″·23 to N. pole. Again, a little later, 21″·44 to S. pole and 20″·83 to N. March 18, λ=309°; 20″·96 to S. pole and 20″·55 to N. March 25, λ=293°; 20″·01 to S. pole and 20″·01 to N. March 27, λ=2°; 20″·28 to S. pole and 20″·28 to N. These measures are not reduced to mean distance.

The Faint Band in the Bright Central Zone c.

April 27, λ=199°; 19″·14 from the S. pole and 18″·39 from the N.

(*e*) *Some Measures of the Breadth of Dark Bands and Bright Zones.*

The Central Zone c.

1897.	*a*	*b* Reduced to Mean Dist.	1897.	*a*	*b* Reduced to Mean Dist.
Mar. 10	λ = 186°	width = 2″·4	Apr. 15	λ = 200°	width = 3″·7
13	304	3·8	26	20	3·2
21	39	3·5	27	200	3·1
25	281	3·0	28	349	3·2
27	2	3·0	30	254	2·3
Apr. 2	80	3·6	May 1	80	2·6
4	20	3·0	3	23	2·6
8	243	3·2	5	321	2·9

Mean 3″·0.

2, 3, *The Zone c, and* 4, 5.

1897.	*a*	*b*	1897.	*a*	*b*
Mar. 10	295°	8″·7	Apr. 24	109°	11″·2
13	358	11·1	26	86	11·0
16	356	10·9	27	200	10·7
19	184	10·2	28	350	11·3
21	39	11·0	30	290	11·3
23	340	10·4	May 1	80	11·7
27	2	10·1	3	23	11·9
Apr. 2	80	11·2	5	321	10·8
4	20	10·5	6	75	11·1
8	225	11·2	8	74	10·9
15	197	11·4	10	356	11·1
23	319	10·4			

Mean 10″·9.

Bright Zone b.

1897.	*a*	*b*		*a*	*b*
Mar. 10	294°	1″·3	Apr. 4	20°	1″·8
19	199	2·1	7	240	1·3
25	293	2·0			

Mean 1″·7.

Dark Band 1.

1897.	*a* °	*b* ″		*a* °	*b* ″
Mar. 10	295	0·8	Apr. 8	243	1·1
19	183	1·2	27	181	1·3
27	127	1·0			

Mean 1″·1.

Dark Band 2, 3.

1897.	*a* °	*b* ″		*a* °	*b* ″
Mar. 10	295	3·1	Apr. 8	207	3·5
13	313	3·8	8	243	3·7
16	80	3·5	15	197	4·0
19	135	3·5	23	355	4·1
19	199	4·3	26	85	3·8
21	40	4·5	30	254	4·5
25	281	3·6	May 1	80	4·6
27	322	3·6	3	21	3·9
Apr. 2	79	3·6	5	321	3·3
8	243	3·9	6	75	4·2

Mean 3″·8 1895–6 3″·5.

Dark Band 4, 5.

1897.	*a* °	*b* ″		*a* °	*b* ″
Mar. 10	295	3·1	Apr. 15	197	3·7
13	313	3·4	23	355	4·1
16	80	3·5	26	85	3·8
21	40	3·2	30	254	4·3
25	281	3·9	May 1	80	4·6
Apr. 2	79	4·0	3	21	3·9
8	207	4·3	5	321	3·7
8	243	3·9	6	75	4·2
8	243	4·3			

Mean 3″·9 1895–6 2″·4.

(*f*) *Measures of Dark and Bright Spots, &c.*

A few estimates and measures of the length of the dark spots, &c., may be added here.

The dark cloud forms or the detached portions of dark band 4. May 1, $\lambda = 116°$; length, 2″. May 8, $\lambda = 136°$; length, 2½″. May 9, $\lambda = 237°$; length, 2½″.

The length of the dark portion of dark band 1 just over (to S. of) the red spot, April 23, $\lambda=31°$; length, 8″·3.

The length of the dark portion of dark band 5, April 23, $\lambda=285°$; length, 4″·9.

The width of the mouth of the bright canal running from the central zone *c* through dark band 3, April 23, $\lambda=285°$; width, 0″·7.

Distance of the point where 2 joins 3 from the *f* shoulder, 8″.

Distance between the *p* and *f* shoulders, 11¼″.

The small, circular, bright spots had a diameter of about 1″·0.

(*g*) *Notes on Satellites and Shadows during Transit.*

Satellite I.

1897 January 27. This satellite passed on to the disc at $9^h\ 10^m$ (*N.A.*). 10^m after ingress it was invisible, and so remained till 11^h, when clouds prevented further observation.

1897 April 22. I. Tr. E. external contact at $8^h\ 58^m$. The satellite moved along dark band 4, and was invisible till $\frac{1}{4}^h$ before egress.

Satellite II.

1897 March 1. II. Tr. I. The satellite moved along the upper (*i.e.* S.) component of the dark double belt just N. of the equator. It was faint at $8^h\ 18^m$, very faint at $8^h\ 25^m$, and invisible at $8^h\ 30^m$.

Satellite III.

1897 March 16. III. Sh. E. at $8^h\ 33^m$ (*N.A.*). The shadow seemed much larger when away from the limb than when near it. It was a very striking object on the disc till within half an hour of egress.

1897 March 23. III. Tr. I. at $6^h\ 20^m$ (*N.A.*). At 7^h and till $8^h\ 30^m$ the satellite was as black as a shadow in transit. At $9^h\ 30^m$ it was invisible. It moved along the N. component of the double dark belt just N. of the equator.

1897 April 28. III. Sh. E. at $8^h\ 24^m$ (*N.A.*). From $7\frac{1}{2}^h$ till $7\frac{3}{4}^h$ the shadow of III. was not far from the limb of *Jupiter*, and was very distinctly elongated and pear-shaped in a direction at right angles to the belts. The pointed end just touched the N. edge of the N. component of the double dark band to the N. of the equator; the wider end lay in the bright zone just N. of the dark belt.

(*h*) *Observations of Phenomena of Jupiter's Satellites with the 9-inch Cooke Equatorial Refractor at Mr. Crossley's Observatory, Bermerside, Halifax, in* 1896–7. By Joseph Gledhill.

Day of Obs.	Satellite.	Phenomenon.	Phase.	G.M.T. of Observation.	G.M.T. of *N. Almanac.*
1897.				h m s	h m s
Jan. 18	I.	Sh. I.	Int. contact	12 14	12 10
	I.	Tr. I.	Int. contact	12 57 30	12 58
27	I.	Tr. I.	Ext. contact	9 11	9 10
Feb. 26	I.	Tr. I.	Ext. contact	10 31	10 33
			Bisection	10 32	
			Int. contact	10 33	
	I.	Sh. I.	Int. contact	10 41	10 38
27	I.	Ec. R.	First seen	10 2 48	10 3 48
			Bisection	10 4	
			Full	10 5	
	I.	Oc. D.	First contact	7 40	7 41
			Bisection	7 42	
			Gone	7 43	
Mar. 1	II.	Tr. I.	Ext. contact	7 57	7 55
			Bisection	7 59	
			Int. contact	8	
	II.	Sh. I.	Int. contact	8 17	8 13
	II.	Tr. E.	Int. contact	10 43	10 46
			Bisection	10 45	
			Ext. contact	10 47	
16	III.	Sh. E.	Int. contact	8 25	8 33
			Bisection	8 27	
			Off	8 30	
17	II.	Oc. D.	Ext. contact	7 25	7 26
Apr. 5	I.	Oc. D.	Ext. contact	10 53	10 53
			Bisection	10 54 30	
			Gone	10 56	
10	III.	Ec. R.	First seen	10 20 43	10 20 23
			Full	10 23	
22	I.	Tr. E.	Ext. contact	8 38	8 38
27	II.	Sh. E.	Int. contact	7 42?	7 48
28	III.	Sh. E.	Int. contact	8 12?	8 24
			Bisection	8 17?	
June 12	II.	Sh. I.	Int. contact	10	9 57
	II.	Tr. E.	Ext. contact	10 24	10 24
14	IV.	Sh. I.	Ext. contact	9 44	9 45
	I.	Sh. I.	Bisection	9 49 30	9 48
			Int. contact	9 51 30	

Notes.

The above are the only observations of these phenomena that were made here. The observing conditions were so bad and the clear nights so few that few observations could be made, and those of poor quality. The following summary will show that an exceptionally bad winter and spring were experienced here:—

	a		*c*	*d*	*e*	*f*	*g*
1896 Oct.	0	2	9	4	10	18	40
Nov.	0	1	10	7	13	18	52
Dec.	0	2	4	2	14	24	24
1897 Jan.	0	4	8	3	13	16	46
Feb.	0	4	4	3	11	18	28
Mar.	0	3	12	1	9	18	48
Apr.	3	3	5	0	8	14	40

a Number of really good nights. *b* Fairly good. *c* Bad.
d Clear all night. *e* Sunless days. *f* Starless nights.
g Number of clear night hours in the month.

Errata in Mr. Gledhill's paper, MONTHLY NOTICES, vol. lvi.

Page 483, line 11, *for* 218° *read* 213°.
„ „ „ 26, *for* 367°·0 *read* 267°·1.
„ 484, line 13, *for* 119°·8 *read* 122°·3.
„ 498, line 11, *for* 7°·4 *read* 8°·4.
„ „ „ 17, *for* 24°·9 *read* 25°·9.
„ „ „ 18, *for* 26°·6 *read* 20°·5.

The values of L and λ were simply approximate values, and no correction was applied for "the differences of successive values of the longitude of *Jupiter's* central meridian."

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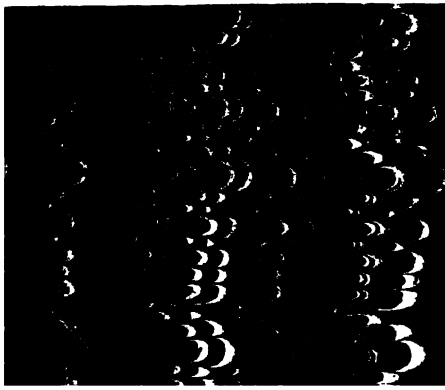

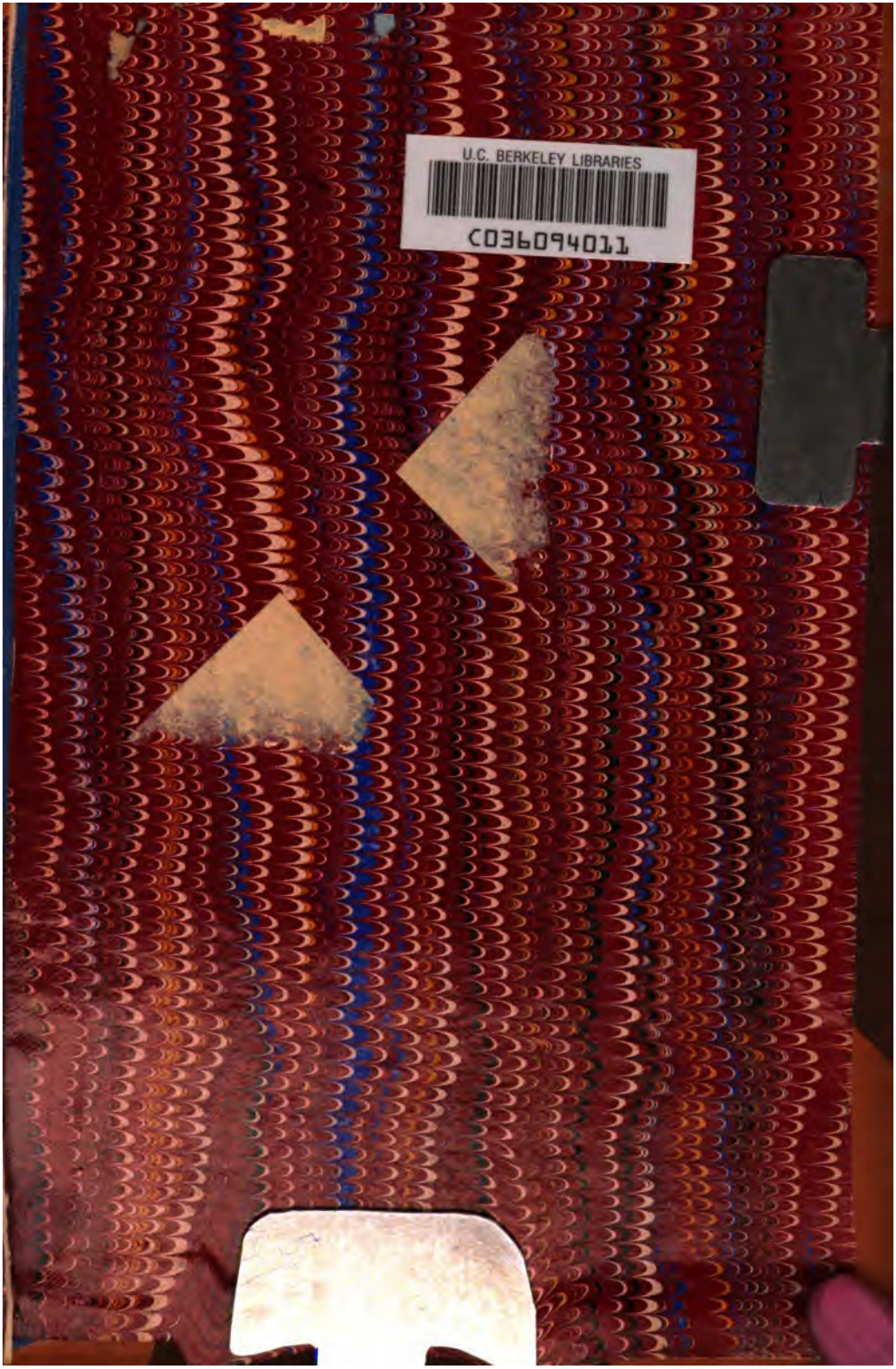
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